JPL NO. 9950 - 1174

VOYAGER 0.2-lbf THRUSTER VALVE ASSEMBLY SHORT PULSE TEST REPORT

85-R-999

(NASA-CR-176121) VOYAGER 0.2-lbf THRUSTER VALVE ASSEMBLY SHORT PULSE TEST REPORT (Rocket Research Corp.) 63 p HC A05/MF A01 CSCL 21H
N85-33185
Unclas
G3/20 22089

Prepared for:

Jet Propulsion Laboratory
California Institute of Technology
4800 Oak Grove Drive
Pasadena, California 91109

April 29, 1985

ROCKET RESEARCH COMPANY

Redmond, Washington

A DIVISION OF ROCKCOR

This report was prepared for the Jet Propulsion Laboratory, California Institute of Technology, sponsored by the National Aeronautics and Space Administration.

VOYAGER 0.2-lbf THRUSTER VALVE ASSEMBLY

SHORT PULSE TEST REPORT

Prepared for:

JET PROPULSION LABORATORY
California Institute of Technology
4800 Oak Grove Drive
Pasadena, California 91109

Prepared by:

ROCKET RESEARCH COMPANY
A Division of ROCKCOR, Inc.
11441 Willows Road
Redmond, Washington 98052

RRC Report No.: 85-R-999

Date: April 29, 1985

Prepared and approved by:

D. R. Johnson
Project Manager

VOYAGER 0.2-lbf T/VA

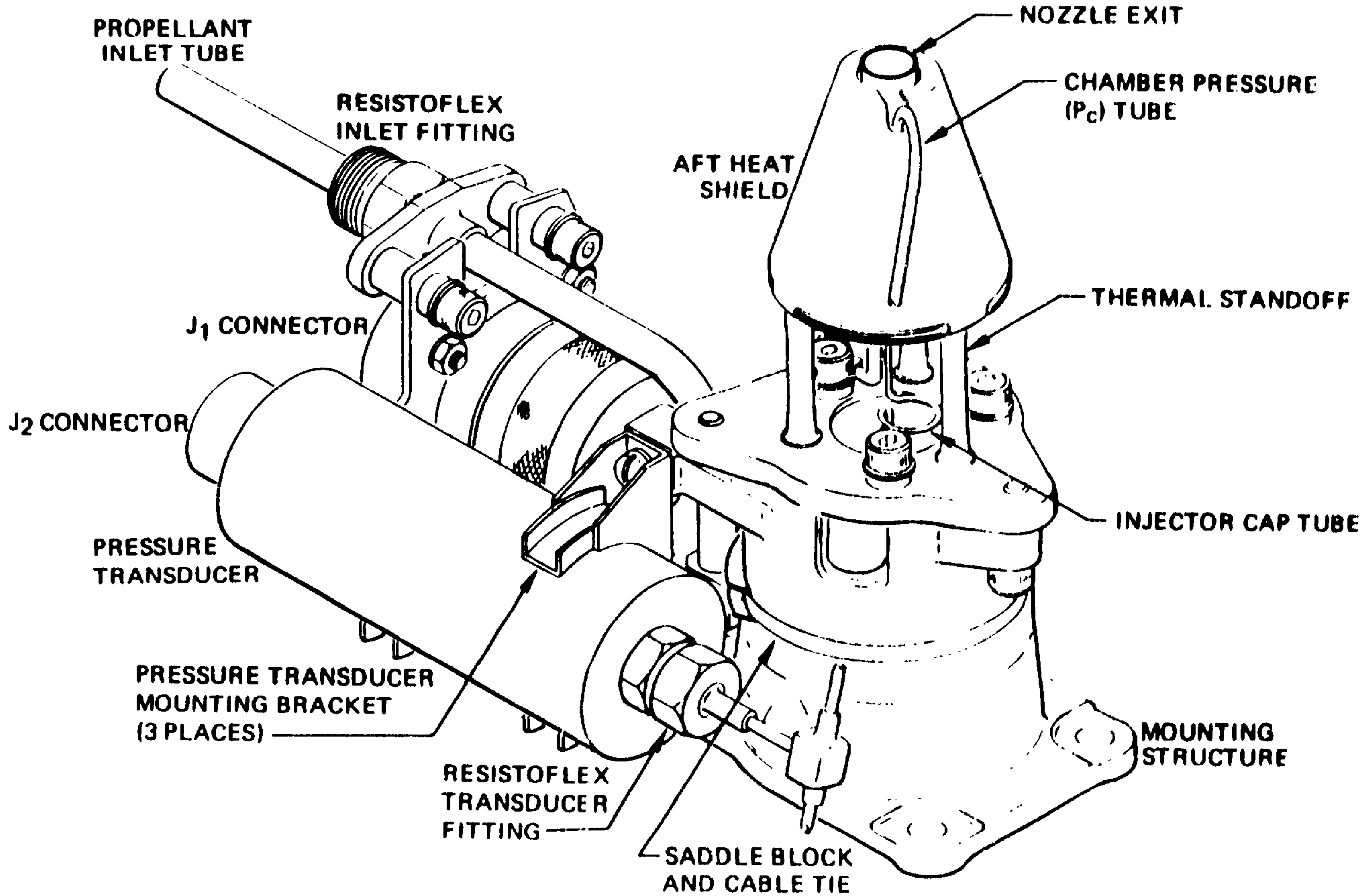


TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF FIGURES (Continued)

LIST OF FIGURES (Continued)

1.0 SUMMARY

This test report documents the short pulse width testing completed on the Voyager 0.2-lbf thruster valve assemblies (T/VA's) under contract 956930 and the disassembly and inspection of T/VA S/N 020 under contract 957181 for Jet Propulsion Laboratory of Pasadena, California. The testing was conducted at Rocket Research Company, Redmond, Washington, beginning October 1984 and ending April 1985.

1.1 PURPOSE

The purpose for performing the short pulse width testing on Voyager 0.2-lbf thruster valve assemblies (T/VA's) was to determine the following:

- Impulse bit versus electrical pulse width.
- Impulse bit variations versus electrical pulse width.
- Whether the short pulses decrease thruster life.

1.2 INTRODUCTION

Seven T/VA's were candidates for the short pulse test program. The seven T/VA's (S/N's 015, 016, 019, 020, 021, 022 and B02A), were processed through prefire functional tests. The functional test results and firing histories were evaluated. T/VA serial numbers 016, 019, 020 and 022 were selected for the short pulse testing and T/VA S/N 021 was selected as the backup unit.

The hot-firing history of these T/VA's is contained in MJS-77 Propulsion Subsystem Test Report, memorandum VGR77 77-132. A pulse and on-time summary is as follows:

T/VA Pulse and On-Time Summary

T/VA S/N	Total Pulses	On-Time (sec)
016	9,955	1,211
019	2,965	426
020	2,530	86,300
022	120,189	58,082

2.0 TEST PLAN

This section presents the Voyager 0.2-lbf T/VA short pulse width test plan. The short pulse test flow plan is shown on Figure 2-1.

2.1 MODIFICATION OF T/VA's

The seven T/VA's, S/N's 015, 016, 019, 020, 021 and B02A, were in various stages of disassembly when they were received. The thermal shroud, pressure transducer, and/or aft heat shield were removed, if not previously removed, so that all units were in the same configuration.

2.2 PREFIRE FUNCTIONAL TESTS

The seven T/VA's were subjected to the following functional tests:

- Thrust control valve response
- Thruster GN_2 flow
- Proof pressure
- External and internal leak
- Heater resistance

On the basis of the functional tests and hot-firing history, four of the seven T/VA's were selected for the characterization test.

2.3 T/VA CHARACTERIZATION TEST NO. 1

Four T/VA's (S/N's 016, 019, 020 and 022), were subjected to characterization test No. 1. If one of the four had not met the original ATP requirements, the backup T/VA S/N 021 would have been installed in its place. The T/VA characterization test duty cycle is shown on Table 2-1. This duty cycle is equivalent to the original ATP duty cycle.

2.4 SHORT PULSE WIDTH TEST NO. 1

The short pulse width test duty cycle is shown on Table 2-2. This duty cycle was used to determine the characteristics of the decrease in impulse bit with the reduction in electrical pulse width and also determine the electrical pulse width that was so short that the thrust control valve did not open.

2.5 SHORT PULSE WIDTH TEST NO. 2

This test is a repeat of short pulse width test No. 1, except that the test sequence is run in the reverse order; i.e., starting with an ON TIME of 3 milliseconds and ending with an ON TIME of 10 milliseconds.

2.6 SHORT PULSE WIDTH TEST NO. 3

This test is a repeat of short pulse test No. 1, except the propellant feed pressure is 190 psia instead of 220 psia.

2.7 SHORT PULSE WIDTH TEST NO. 4

This test is a repeat of short pulse width test No. 2, except the propellant feed pressure is 190 psia instead of 220 psia.

2.8 ABBREVIATED LIFE TEST

The abbreviated life test duty cycle is shown on Table 2-3. The abbreviated life test was completed in four sequences. Each of the four sequences was followed by a repeat of a short pulse width test. Sequences 1, 2, and 4 each contained 5,000 pulses and sequence 3 contained 10,000 pulses for a total of 25,000 pulses. The ON TIME for the abbreviated life test was varied from 3.3 to 4.0 milliseconds, depending on the particular T/VA and abbreviated life test segment, to obtain an impulse bit that was 20% to 30% of the 10-millisecond pulse impulse bit. The abbreviated life test electrical pulse widths are shown on Table 2-4.

2.9 T/VA CHARACTERIZATION TEST NO. 2

This test was a repeat of T/VA characterization test No. 1. The purpose of this test was to determine if there was significant performance degradation due to the short pulse/ abbreviated life testing.

2.10 POSTFIRE FUNCTIONAL TESTS

This test was a repeat of the prefire functional test. The purpose of this test was to determine if there was any significant functional degradation of the T/VA's, especially pertaining to the thrust control valve response and the thruster GN_2 flow.

T/VA CHARACTERIZATION TEST DUTY CYCLE

Test Sequence	Propellant Feed Pressure (psia)	No. of Pulses	On Time (sec)	Off Time (sec)	Initial Temp. (°F)
1	350 ± 5	100	0.020	3.98	325 ± 25
2	350 ± 5	20	0.10	0.90	Existing
3	350 ± 5	1	200	—	Existing
4	150 ± 5	1	200	—	Existing

Table 2-1

Table 2-2
SHORT PULSE WIDTH TEST DUTY CYCLE

Test Sequence	Propellant Feed Pressure (psia)	No. of Pulses	On Time (ms)	Off Time (sec)	Initial Temp. (°F)
1	220 ± 5	10	10	60	325 ± 25
2	220 ± 5	10	9	60	325 ± 25
3	220 ± 5	10	8	60	325 ± 25
4	220 ± 5	10	7.5	60	325 ± 25
5	220 ± 5	10	7.0	60	325 ± 25
6	220 ± 5	10	6.5	60	325 ± 25
7	220 ± 5	10	6.0	60	325 ± 25
8	220 ± 5	10	5.5	60	325 ± 25
9	220 ± 5	10	5.0	60	325 ± 25
10	220 ± 5	10	4.5	60	325 ± 25
11	220 ± 5	10	4.0	60	325 ± 25
12	220 ± 5	10	3.5	60	325 ± 25
13	220 ± 5	10	3.0	60	325 ± 25

Table 2-3
ABBREVIATED LIFE TEST DUTY CYCLE

Test Sequence	Propellant Feed Pressure (psia)	No. of Pulses	On Time (ms)	Off Time (sec)	Initial Temp. (°F)
1	220 ± 5	5,000	3.3 3.5	30	325 ± 25
●	REPEAT SHORT PULSE WIDTH TEST				
2	220 ± 5	5,000	4	30	325 ± 25
●	REPEAT SHORT PULSE WIDTH TEST				
3	220 ± 5	10,000	3.6—3.8	30	325 ± 25
●	REPEAT SHORT PULSE WIDTH TEST				
4	220 ± 5	5,000	3.6—3.8	30	325 ± 25
●	REPEAT SHORT PULSE WIDTH TEST				

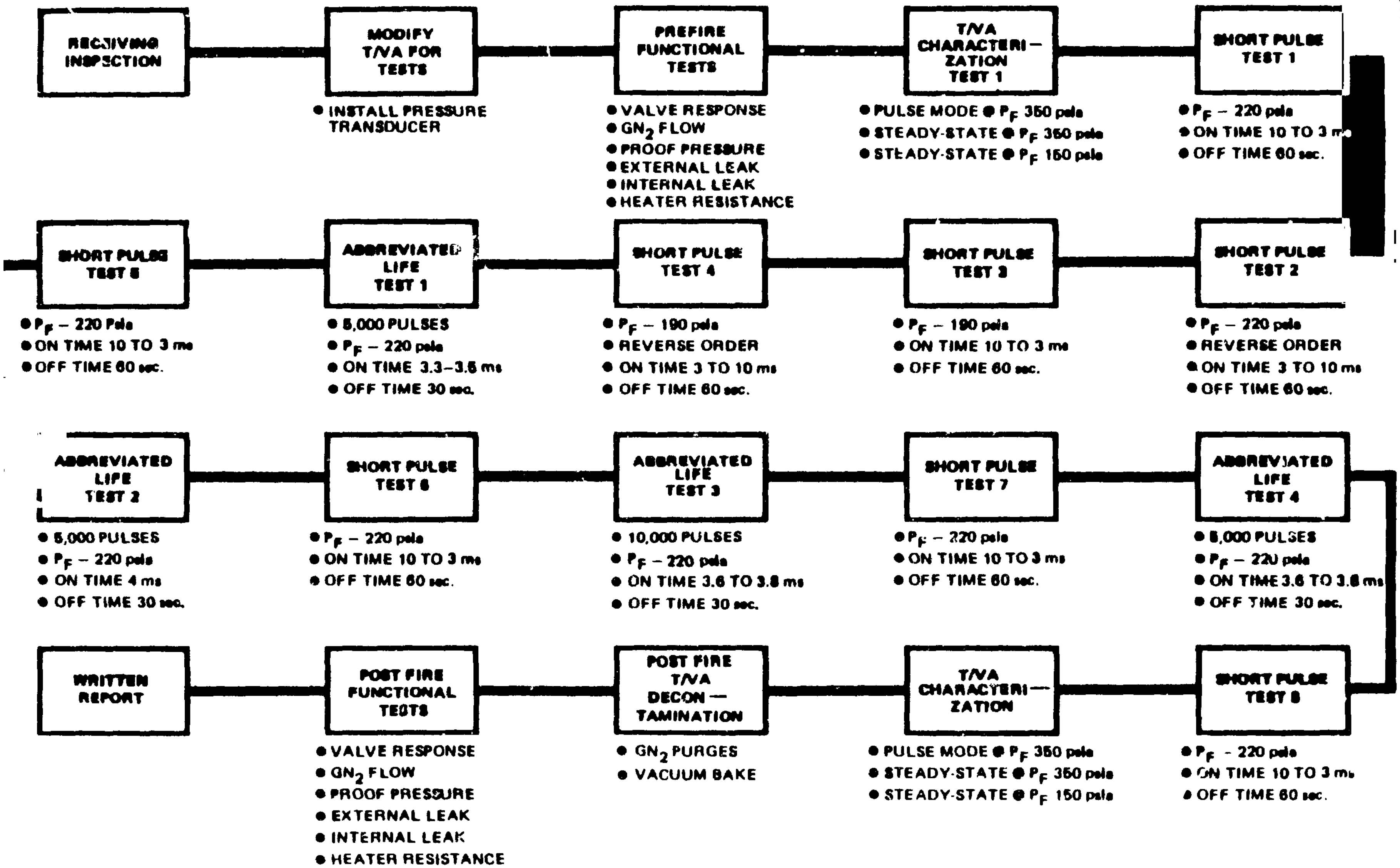
ABBREVIATED LIFE TEST
ELECTRICAL PULSE WIDTHS (ms)

TEST NO.	T/VA S/N 16	T/VA S/N 19	T/VA S/N 20	T/VA S/N 22
1	3.3	3.5	3.5	3.4
2	4.0	4.0	4.0	4.0
3	3.6	3.7	3.8	3.7
4	3.6	3.7	3.8	3.7

OFF TIME — 30 seconds

Table 2-4

VOYAGER 0.2-lbf T/VA SHORT PULSE TEST FLOW PLAN



11154-47A

Figure 2-1

3.0 TEST FIRING SETUP AND INSTRUMENTATION

3.1 TEST FIRING SETUP

3.1.1 Test Fixture

Four thruster valve assemblies (T/VA's) (S/N's 016, 019, 020 and 022), were installed on the test firing fixture, as shown in Figures 3-1, 3-2, and 3-3. Thermocouples were welded to the thrust chamber bodies to provide thrust chamber temperature, as shown in Figure 3-1. The T/VA chamber pressure (P_C) tubes were connected to the Taber pressure transducers using specially prepared adapters to reduce the holdup volume. Transducers with a 0- to 300-psia range were used for the characterization tests, and transducers with a 0- to 50-psia range were used for the short pulse width and abbreviated life tests.

3.1.2 Altitude Chamber

The test firing fixture with the T/VA's mounted on it was installed in the altitude chamber, as shown by the schematic drawing on Figure 3-4. Figures 3-1, 3-2 and 3-3 also show the T/VA's installed in the altitude chamber.

3.2 TEST INSTRUMENTATION

The instrumentation used on this test is shown on Table 3-1 and Figures 3-5, 3-6, 3-7 and 3-8. The test instrumentation calibrations were performed to secondary standards traceable to the National Bureau of Standards.

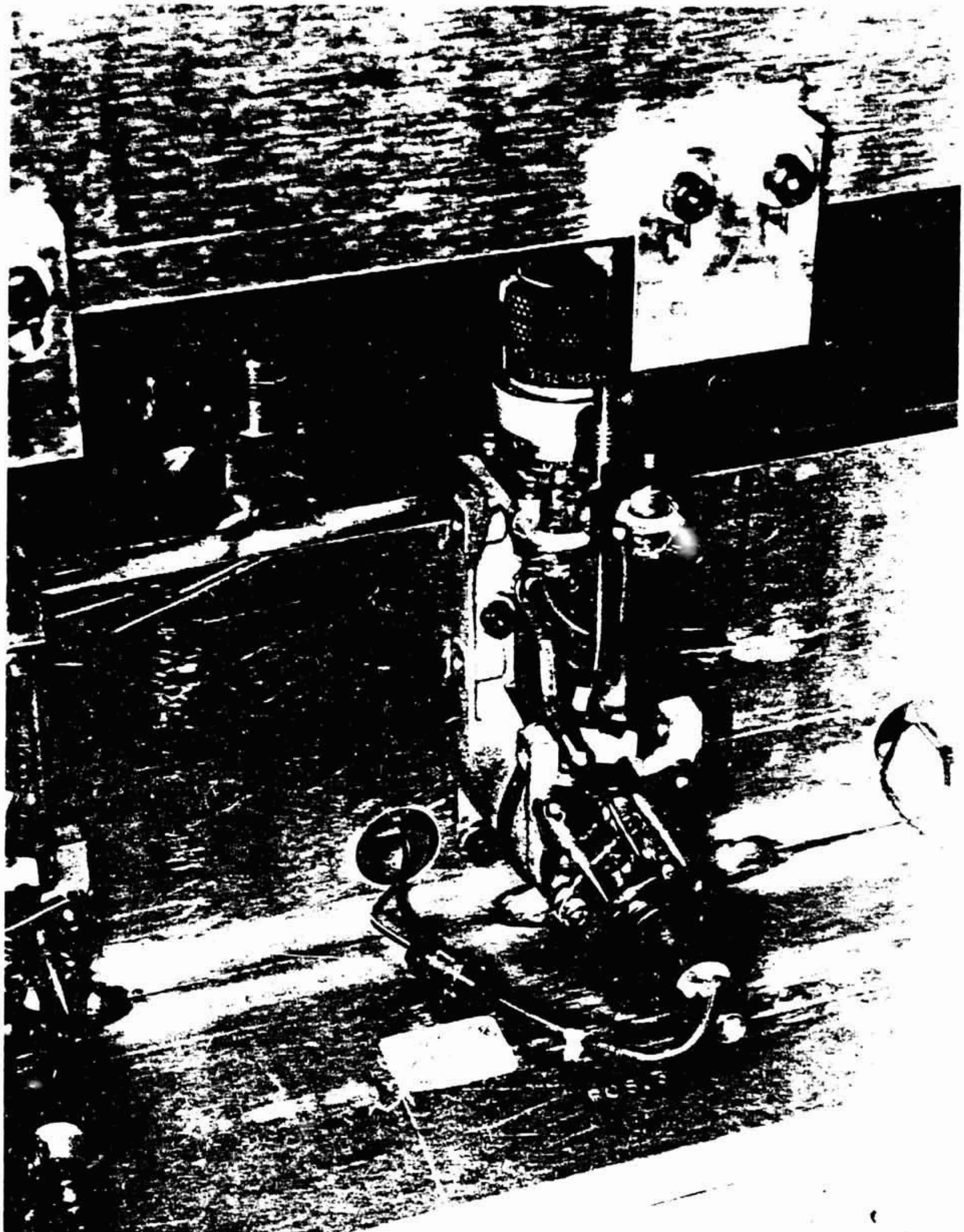
An accurate time base for the electrical pulse signal was more difficult to obtain due to the fact that the RRC data acquisition system normally takes data at one millisecond intervals and this test required data samples at each one-tenth millisecond. In order to accomplish this, the data acquisition system was modified to speed up the time base by a factor of 10; e.g., for each 6 seconds of real time, the data acquisition time base registers 60 seconds. The electrical pulse widths were then calibrated.

Table 3-1
TEST INSTRUMENTATION

Parameter	Symbol	Range	Recording Technique		
			SCR	Quick Look	DDS
Chamber pressure — Thruster	P_c	0 — 300 psia and 0 — 50 psia	—	X	X
Propellant feed pressure	P_f	0 — 400 psig	—	X	X
Propellant temperature	T_f	0 — 5 mv	—	—	X
Altitude chamber pressure	P_a	0 — 1 osia	—	—	X
Sightglass level	H_{SG}	N/A	—	—	Manual
Valve voltage	V_E	0 — 30 vdc	—	X	X
Valve current	I	0 — 0.25 amps	—	X	X
Thruster heater voltage	V_H	0 — 30 vdc	—	—	—
Thrust chamber temperature	T_C	0 — 50 mv	X	—	X

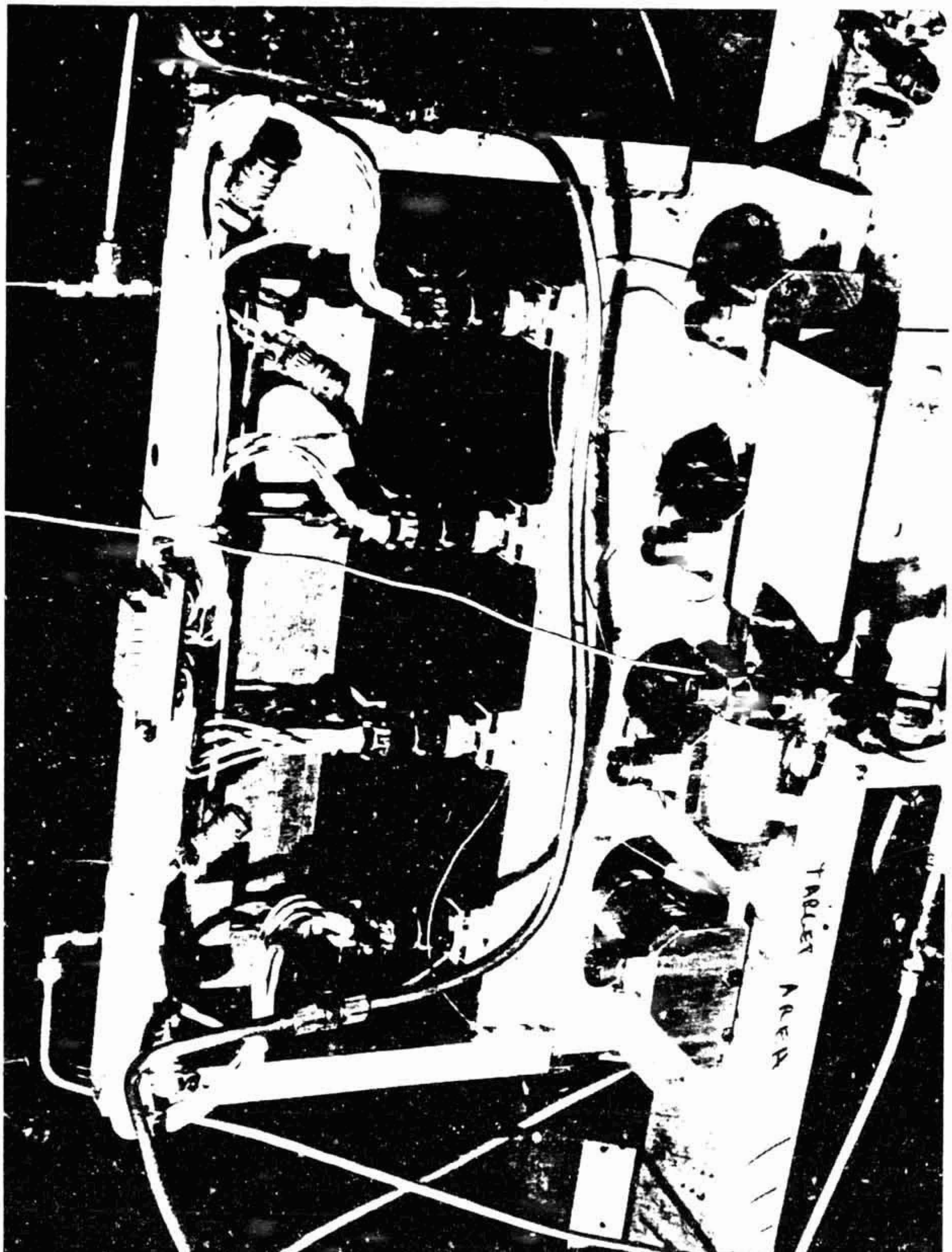
Table 3-1

0.2 lbf T/VA SHORT PULSE TEST FIRING SETUP



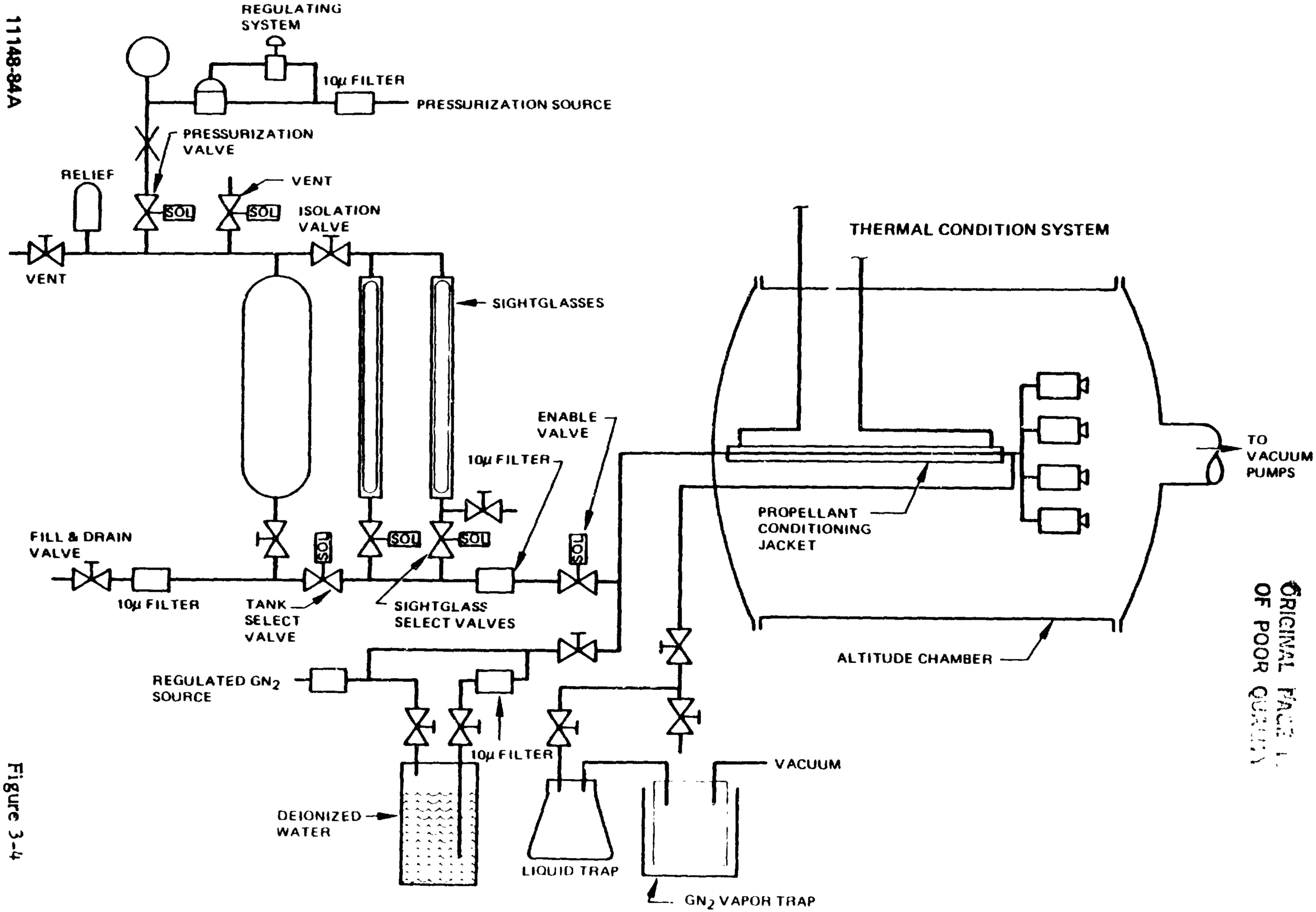
ORIGINAL PAGE IS
OF POOR QUALITY

0.2 lbf T/VA SHORT PULSE TEST FIRING SETUP



0.2 lbf T/VA SHORT PULSE TEST SETUP

T/VA FIRING TEST SETUP

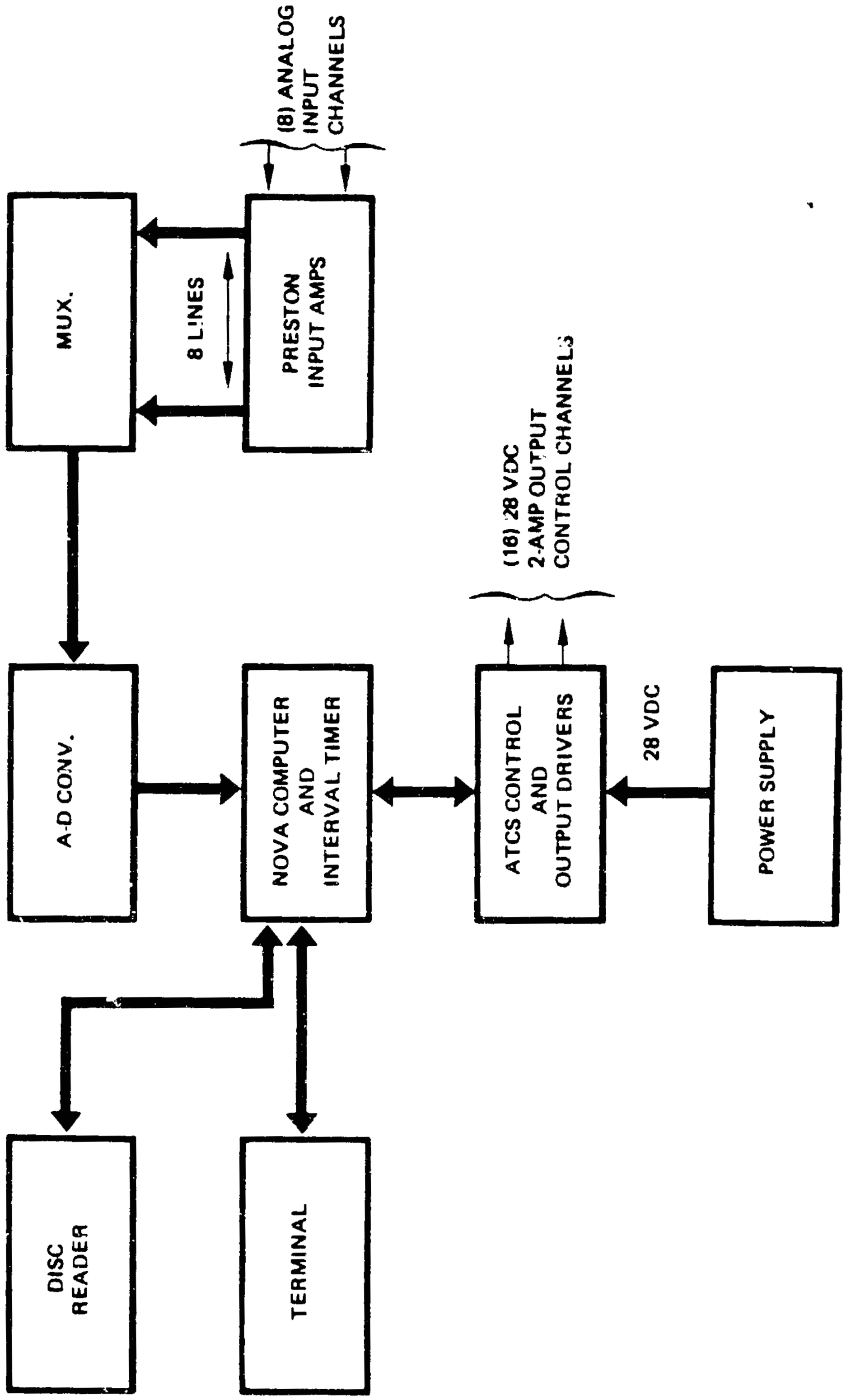


11148-84A

Figure 3-4

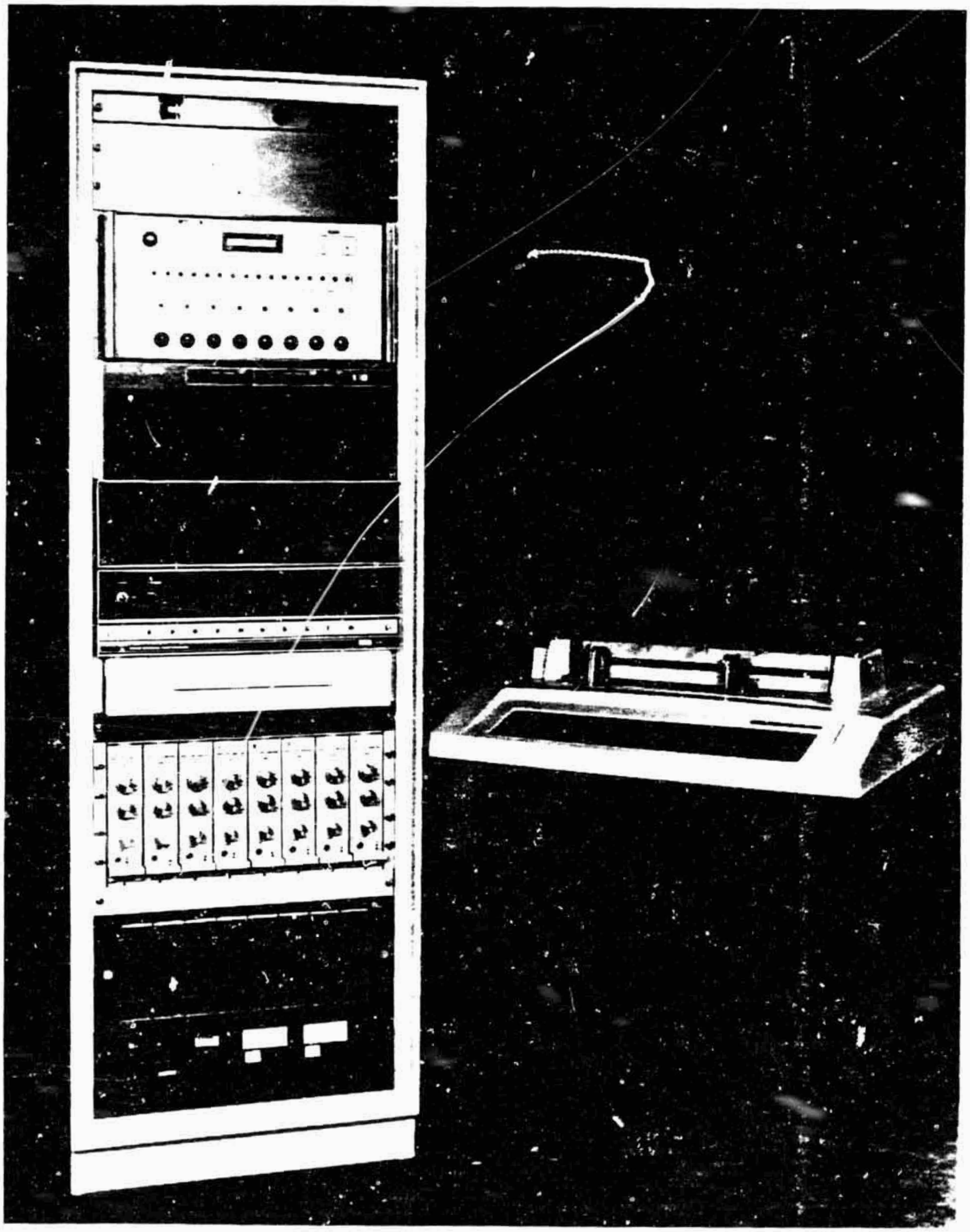
ORIGINAL PAGE IS OF POOR QUALITY

ATCS BLOCK DIAGRAM



ORIGINAL PAGE IS
OF POOR QUALITY

AUTOMATIC TEST CONTROL SYSTEM



IGH-SPEEL ˈIGITAL DATA SYSTEM
BLOCK DIAGRAM

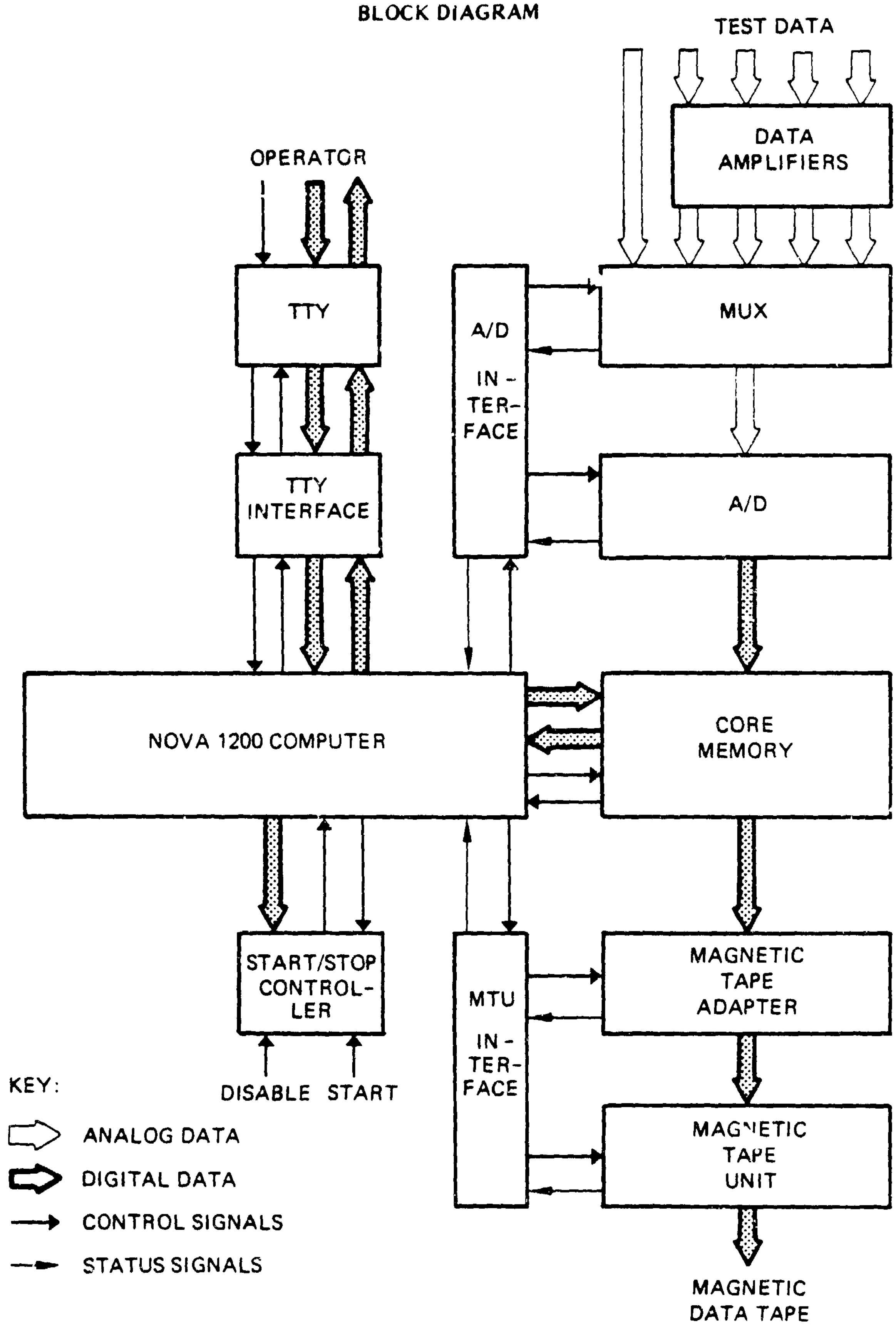
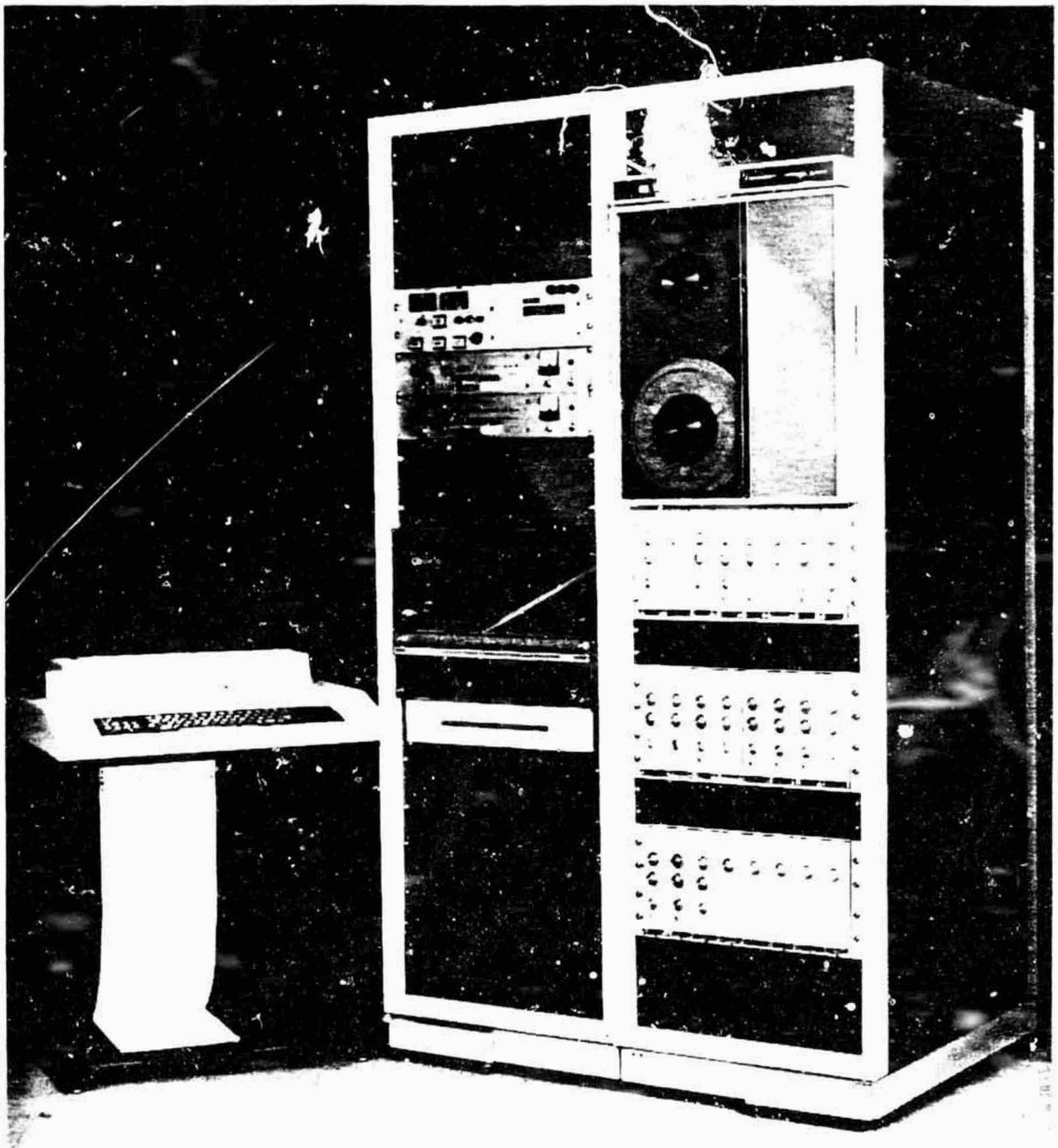


Figure 3-7

DIGITAL DATA ACQUISITION SYSTEM



4.0 TEST RESULTS

4.1 FUNCTIONAL TESTS

The functional test results of the T/VA GN_2 flow and the valve response time are shown on Table 4-1.

Inspection of the data on the T/VA GN_2 flow test reveals the following:

T/VA S/N 016 - No significant decrease in flow rate.

T/VA S/N 019 - No significant decrease in flow rate.

T/VA S/N 020 - Dramatic decrease in flow rate. This indicates partial flow blockage of the thruster and will be discussed in Sections 4.2, 4.3 and 5.0.

T/VA S/N 022 - Slight decrease in flow rate, but the postfire reading at [illegible] psig may be an error as the propellant flow rate and thrust measured during characterization test No. 2 shows a change of approximately 5 percent.

The valve response time data indicates that there is no significant increase in response time.

The proof pressure, internal and external leakage, and heater resistance tests were performed with acceptable results.

4.2 CHARACTERIZATION TESTS

The results of characterization tests 1 and 2, along with the original acceptance test (ATP) data are summarized in Table 4-2.

A review of the characterization and original acceptance test (ATP) data reveals the following:

T/VA S/N 016 - There are no significant changes in any of the performance parameters.

T/VA S/N 019 - The data indicates that there was a decrease in the thrust level of 5 percent for both sequences 3 and 4. The other performance parameters show no significance changes. The 84% roughness during ATP was due to a unique transient condition. All performance parameters meet the original ATP requirements.

T/VA S/N 020 - There is a 70-percent decrease in thrust from characterization test No. 1 to characterization test No. 2. This decrease was caused by partial flow blockage as confirmed by the thruster GN_2 flow test. The abbreviated life test data shows that this flow blockage occurred between pulse 3,000 and 4,000 of the third abbreviated life test sequence; i.e., between the 13,000th and 14,000th pulses of the 25,000-pulse abbreviated life test. Figure 4-45 indicates that there was little performance degradation over the remainder of the testing; i.e., from 14,000th pulse to the 25,000th pulse.

T/VA S/N 022 - The data indicates that there was a decrease in the thrust level of approximately 5 percent for both sequences 3 and 4. The other performance parameters show no significant changes.

4.3 SHORT PULSE WIDTH TESTS

Figure 4-1 presents a curve of average impulse bit as a percent of the impulse bit at an electrical pulse width of 10 milliseconds of the three T/VA's S/N 016, 019, and 022 versus electrical pulse width. Thus, by definition, a data point at 10 milliseconds would be 100 percent.

The data from short pulse tests 1, 5 and 8 are plotted. Short pulse test 1 was run prior to the abbreviated life test. Short pulse test 5 was run after the first segments of the abbreviated life test; i.e., after 5,000 pulses. Short pulse test 8 was run after the conclusion of the abbreviated life test; i.e., after 25,000 pulses. Short pulse tests 2, 6 and 7 were omitted for clarity.

Figures 4-2, 4-3, 4-4, 4-5, 4-6 and 4-7 show the same type of curve as 4-1, except they present data from short pulse tests 1, 2, 5, 6, 7 and 8 individually and respectively.

The data from the testing of T/VA S/N 020 has been omitted from these curves because of the partial flow blockage sustained during the third segment of the abbreviated life test. Data from short pulse tests 3 and 4 have been omitted because they were run at a propellant feed pressure of 190 psia instead of 220 psia.

Figure 4-8 presents a curve of average impulse bit of the three T/VA's S/N's 016, 019 and 022 versus electrical pulse width. The data from short pulse tests 1, 5 and 8 are plotted. Short pulse tests 2, 6 and 7 were omitted for clarity.

Figures 4-9, 4-10, 4-11, 4-12, 4-13 and 4-14 show the same type of curve as Figure 4-8, except they present data from short pulse tests 1, 2, 5, 6, 7 and 8 individually and respectively.

Figures 4-15 through 4-22 present curves of average impulse bit versus electrical pulse width for short pulse tests 1 through 8. T/VA S/N's 016, 019, 020 and 022 data are plotted individually on each figure.

Figure 4-23 through 4-30 present pulse-to-pulse impulse bit variation versus electrical pulse width for short pulse tests 1 through 8. T/VA S/N's 016, 019, 020 and 022 data are plotted individually on each figure.

Figures 4-31 through 4-43 show typical pulse shapes for electrical pulse widths from 10 to 3 milliseconds.

Figure 4-44 presents a curve of average impulse bit of the three T/VA's S/N's 016, 019 and 022 versus accumulated life.

Figure 4-45 presents a curve of average impulse bit versus accumulated life for the T/VA S/N 020. This T/VA sustained partial flow blockage during the abbreviated life testing. The blockage occurred between the 13,000th pulse and the 14,000th pulse of the abbreviated life test. This data indicates that there was very little performance degradation over the remainder of the testing.

T/VA GN_2 FLOW AND VALVE RESPONSE TESTS

T/VA S/N	T/VA GN_2 Flow (ml/min)						Valve Response Time (ms)					
	ATP		Pre-Fire		Post-Fire		Pre-Fire			Post-Fire		
	5 psig	10 psig	5 psig	10 psig	5 psig	10 psig	22 vdc	29.5 vdc	34 vdc	22 vdc	29.5 vdc	34 vdc
16	155	263	189	275	178	295	5.0	3.5	3.5	5.3	3.7	3.2
19	160	268	181	275	163	263	5.5	3.5	3.0	5.6	4.0	3.6
20	173	293	178	245	28	36	5.5	4.0	3.0	6.0	4.1	3.5
22	160	263	160	268	152	220	6.0	4.5	3.9	6.5	4.4	4.0

Table 4-1

Table 4-2
CHARACTERIZATION TEST SUMMARY

Parameter	Characterization Test Seq.	Original ATP Criteria	T/VA S/N 016			T/VA S/N 018			T/VA S/N 020			T/VA S/N 022		
			Orig ATP	* CT-1	** CT-2	Orig ATP	CT-1	CT-2	Orig ATP	CT-1	CT-2	Orig ATP	CT-1	CT-2
Thrust — Steady state (lbf)	3	0.207—0.228	0.218	0.225	0.220	0.222	0.220	0.209	0.224	0.215	0.060	0.217	0.214	0.203
	4	0.0888—0.102	0.095	0.101	0.096	0.098	0.097	0.092	0.098	0.098	0.030	0.094	0.095	0.089
Specific Impulse — Steady state (lbf-sec/lbm)	3	220 min	229	237	236	234	235	233	232	239	224	233	235	232
	4	210 min	221	232	228	227	229	239	226	235	216	223	228	23
Roughness — Steady state (%)	3 & 4	± 50% max	10.0	2.9	6.5	84.0	15.5	6.6	22.0	4.4	6.7	26.2	12.0	12.8
Rise response — Steady state (ms)	3	45 max to 10%	21	27	23	18	23	26	18	33	58	18	27	27
		175 max to 90%	45	124	76	37	82	91	40	155	185	37	118	139
	4	45 max to 10%	24	25	25	20	26	27	20	37	83	18	26	31
		175 max to 90%	50	74	78	46	74	87	47	90	229	58	71	86
Decay response — Steady state (ms)	3	200 max to 10%	100	133	132	102	134	130	92	156	168	95	123	124
	4	200 max to 10%	128	149	149	121	143	148	118	141	202	130	141	149
Impulse Bit Repeatability — Pulse mode (%)	1	± 15% max	0.8	0.3	0.5	0.5	0.4	0.5	0.6	0.3	0.4	1.2	0.6	1.2
	2	± 15% max	0.2	0.4	0.2	0.7	0.2	0.3	0.2	0.2	1.5	0.8	0.9	0.6
Centroid Repeatability — Pulse mode (%)	1	± 10% max	0	0.4	0.8	0.8	0.4	0.8	1.8	0.3	1.2	0	0.4	1.3
	2	± 20% max	0.6	0.4	0.4	0.6	0.8	0.4	0.6	1.0	1.1	1.2	0.8	0.4
Rise response — Pulse mode (ms)	1	30 max to 10%	19	17	20	16	19	21	17	23	26	16	20	20
	2	30 max to 10%	17	20	21	14	22	23	15	24	30	14	21	21
	1	80 max to 90%	38	35	38	30	36	40	29	48	80	28	40	40
	2	80 max to 90%	37	62	62	31	67	65	31	75	86	31	68	74
Decay Response — Pulse mode (ms)	1	1200 max to 10%	160	220	250	180	210	200	130	350	600	130	270	220
	2	1200 max to 10%	100	130	13^	100	140	130	80	160	250	90	140	120

*CT-1, Characterization test prior to short pulse testing.

**CT-2, Characterization test after short pulse testing.

OF POOR QUA...

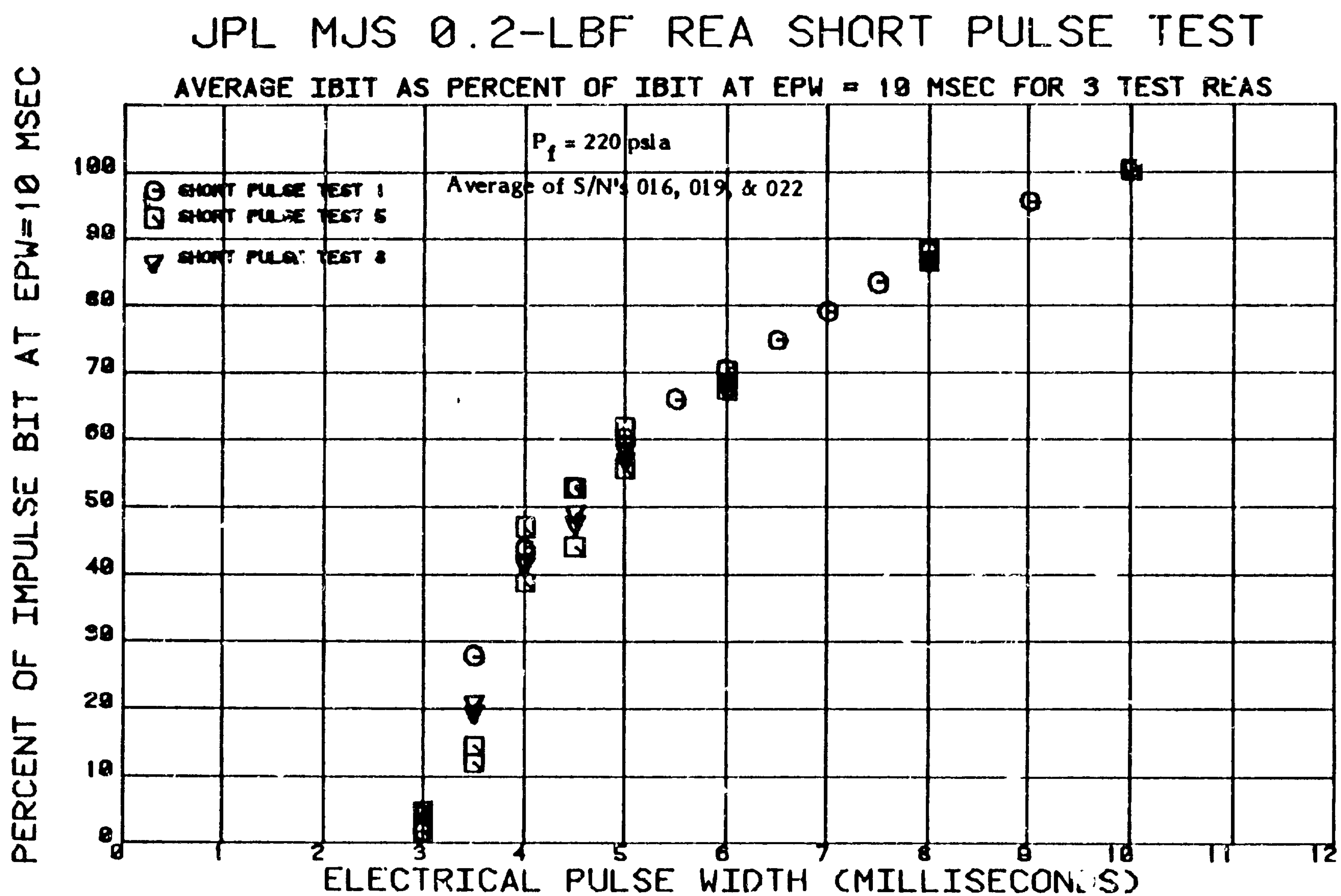
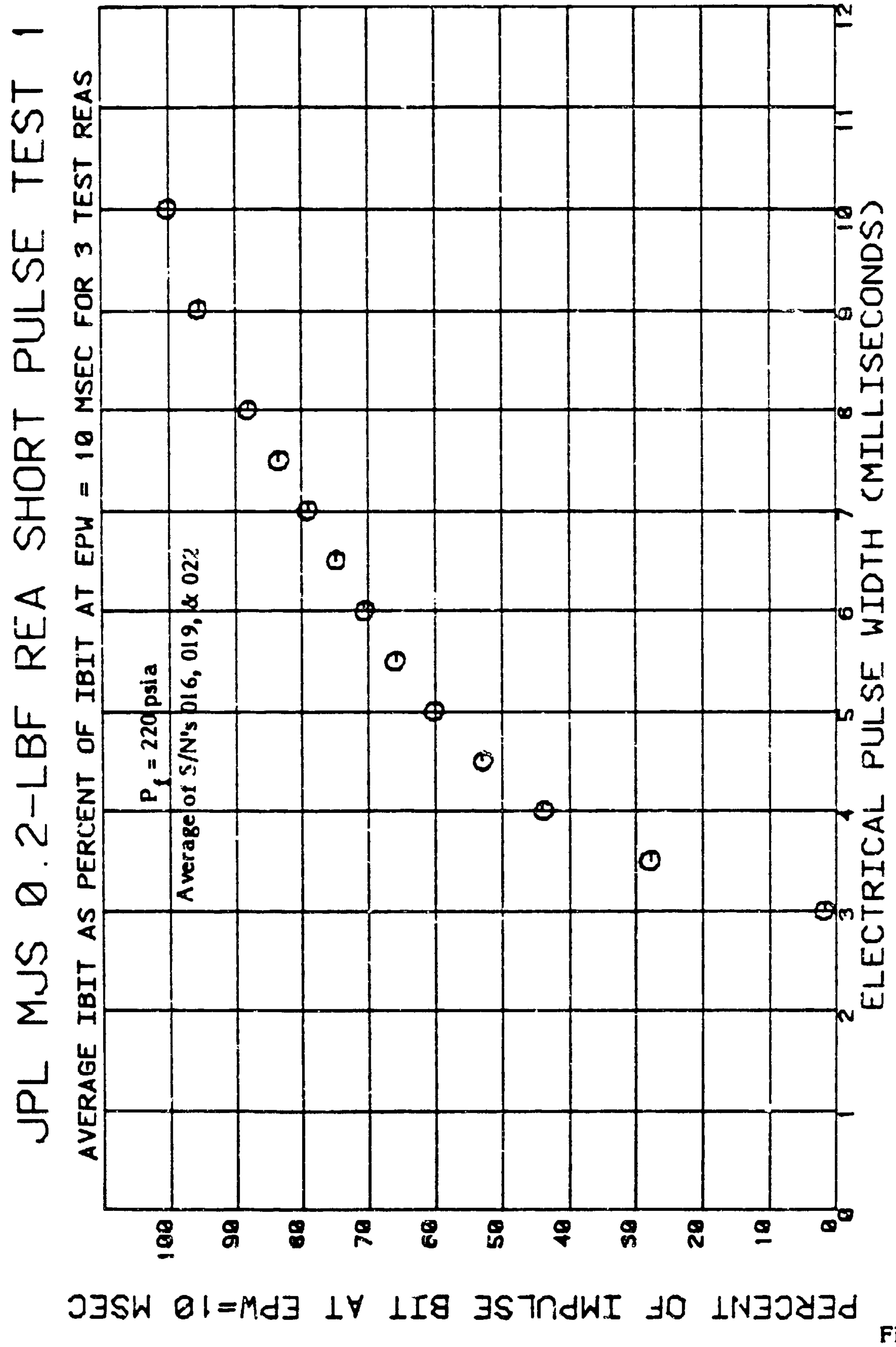

JPL MJS 0.2-LBF REA SHORT PULSE TEST
AVERAGE IBIT AS PERCENT OF IBIT AT EPW = 10 MSEC FOR 3 TEST REAS
P_f = 220 psia
Average of S/N's 016, 019, & 022
SHORT PULSE TEST 1
SHORT PULSE TEST 5
SHORT PULSE TEST 8
PERCENT OF IMPULSE BIT AT EPW=10 MSEC
0
10
20
30
40
50
60
70
80
90
100
ELECTRICAL PULSE WIDTH (MILLISECONDS)
0
1
2
3
4
5
6
7
8
9
10
11
12

Figure 4-1



JPL MJS 0.2-LBF REA SHORT PULSE TEST 1
AVERAGE IBIT AS PERCENT OF IBIT AT EPW = 10 MSEC FOR 3 TEST REAS
P_f = 220 psia
Average of S/N's 016, 019, & 022
ELECTRICAL PULSE WIDTH (MILLISECONDS)
PERCENT OF IMPULSE BIT AT EPW=10 MSEC
0
1
2
3
4
5
6
7
8
9
10
11
12
0
10
20
30
40
50
60
70
80
90
100

Figure 4-2

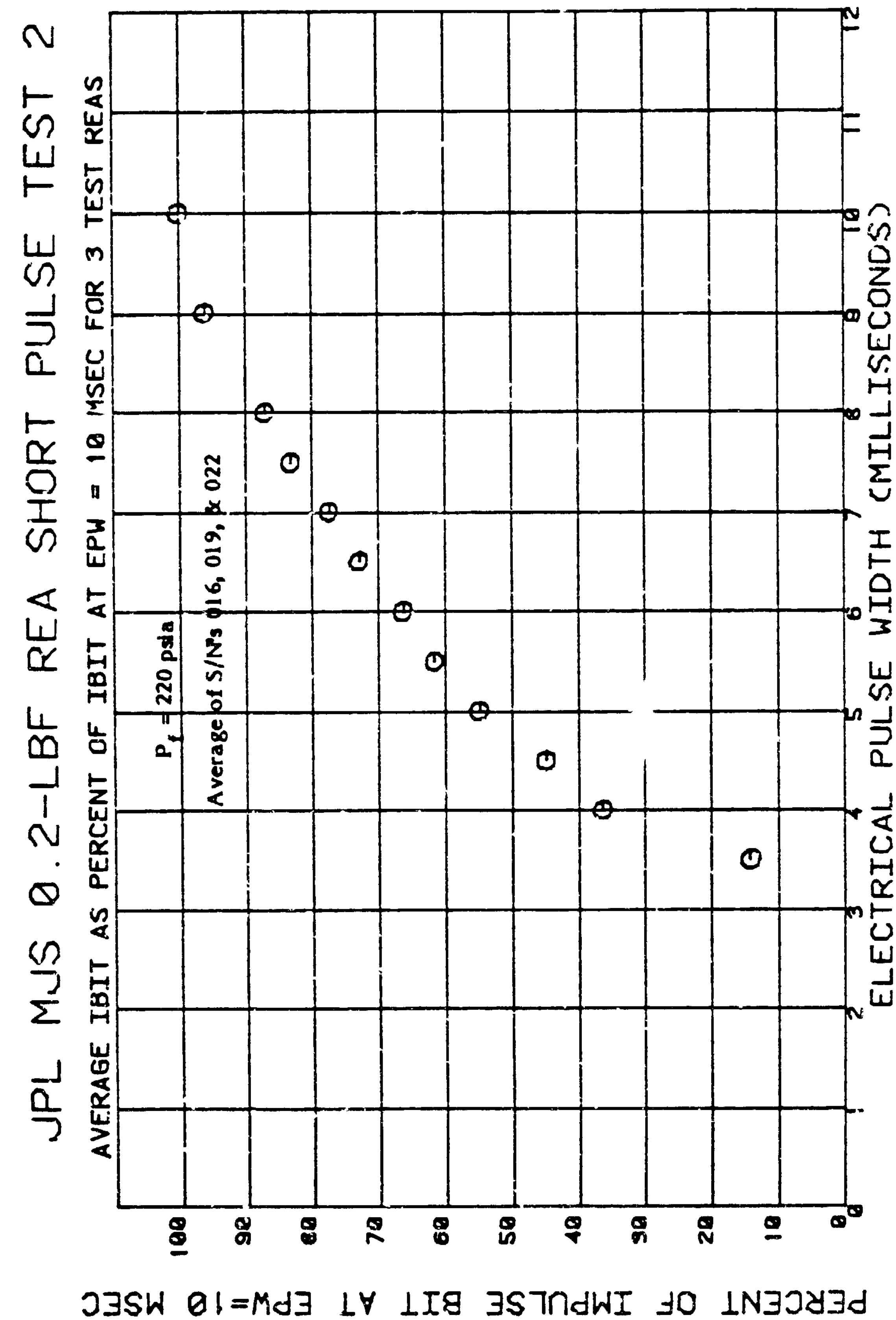

JPL MJS 0.2-LBF REA SHORT PULSE TEST 2
AVERAGE IBIT AS PERCENT OF IBIT AT EPW = 10 MSEC FOR 3 TEST REAS
P_f = 220 psia
Average of S/N's 016, 019, & 022
PERCENT OF IMPULSE BIT AT EPW=10 MSEC
ELECTRICAL PULSE WIDTH (MILLISECONDS)
0
10
20
30
40
50
60
70
80
90
100
1
2
3
4
5
6
7
8
9
10
11
12

Figure 4-3

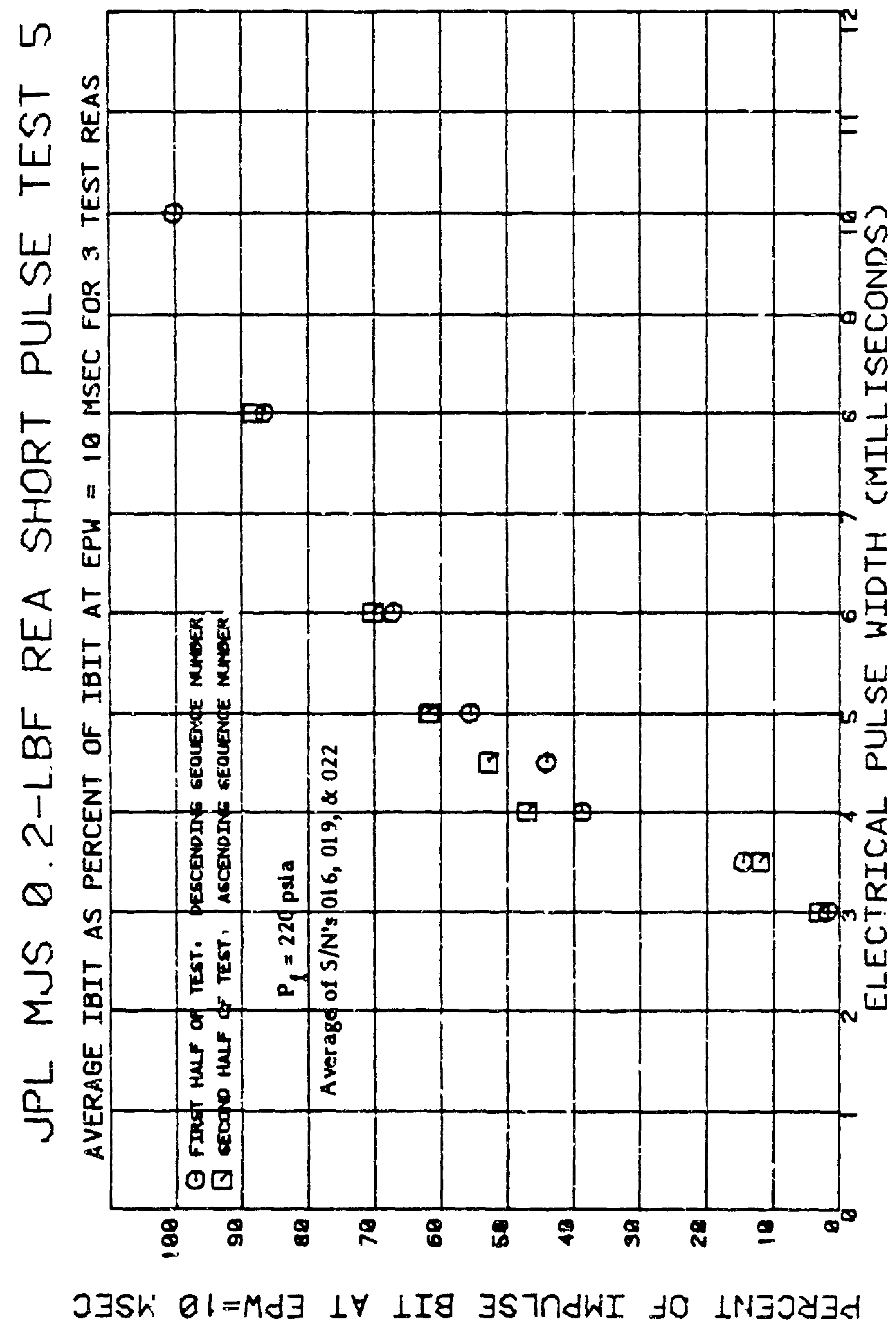

JPL MJS 0.2-LBF REA SHORT PULSE TEST 5
AVERAGE IBIT AS PERCENT OF IBIT AT EPW = 10 MSEC FOR 3 TEST REAS
FIRST HALF OF TEST. DESCENDING SEQUENCE NUMBER
SECOND HALF OF TEST. ASCENDING SEQUENCE NUMBER
P_f = 220 psia
Average of S/N's 016, 019, & 022
PERCENT OF IMPULSE BIT AT EPW=10 MSEC
ELECTRICAL PULSE WIDTH (MILLISECONDS)
0
10
20
30
40
50
60
70
80
90
100
1
2
3
4
5
6
7
8
9
10
11
12

Figure 4-4

ORIGINAL PAGE IS
OF POOR QUALITY

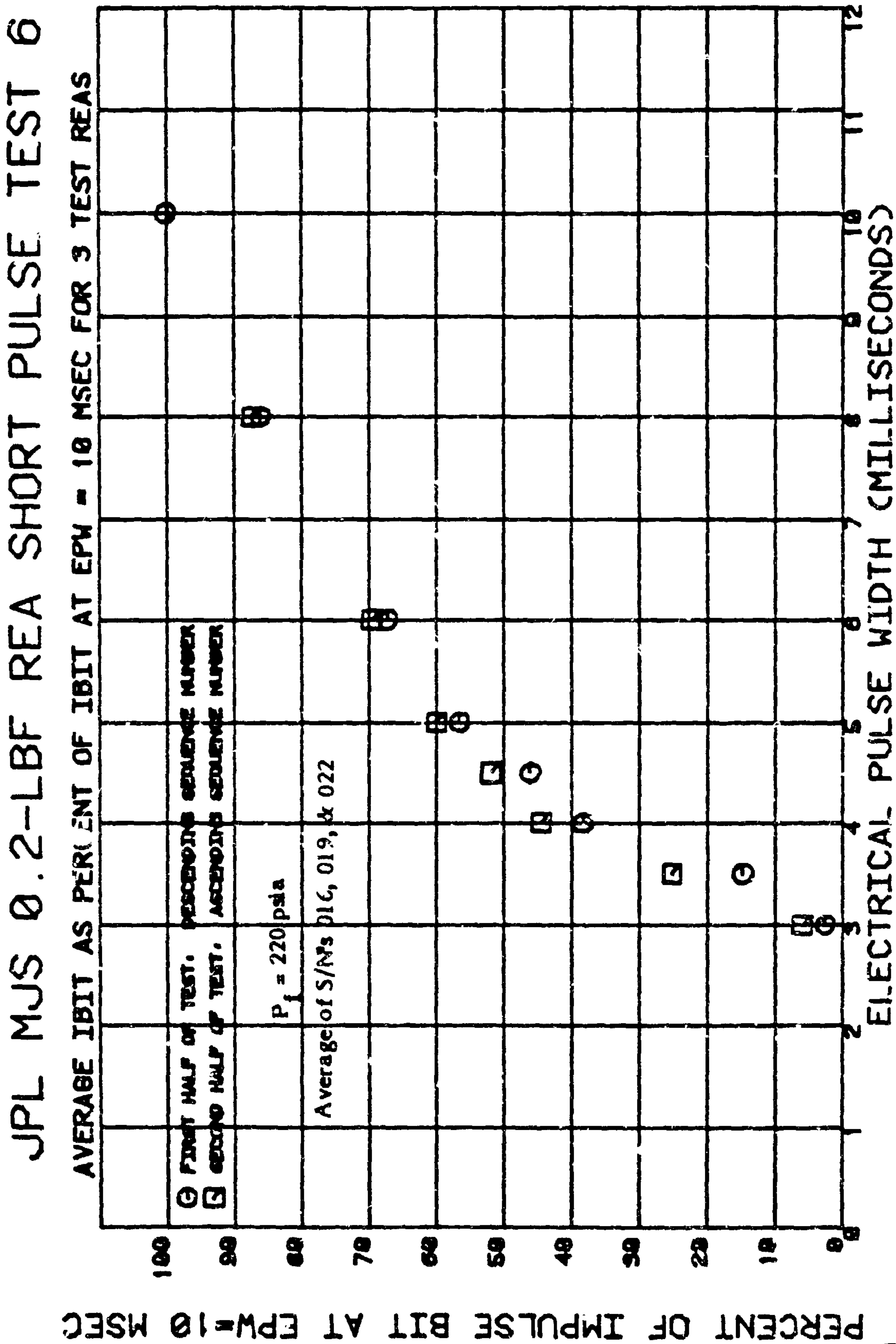
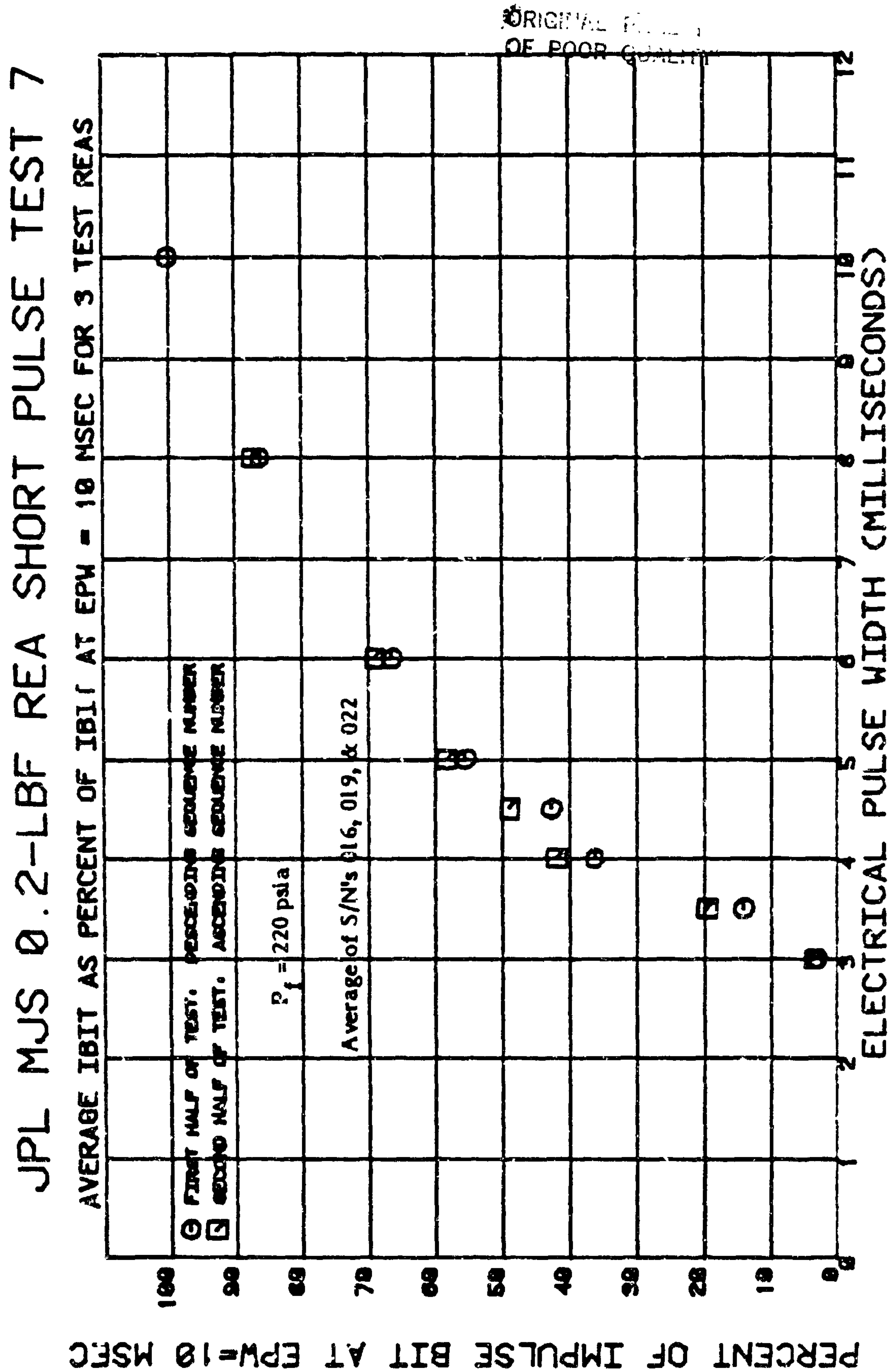


Figure 4-5



JPL MJS 0.2-LBF REA SHORT PULSE TEST 7
AVERAGE IBIT AS PERCENT OF IBIT AT EPW = 10 MSEC FOR 3 TEST REAS
FIRST HALF OF TEST. DESCENDING SEQUENCE NUMBER
SECOND HALF OF TEST. ASCENDING SEQUENCE NUMBER
P_f = 220 psia
Average of S/N's 016, 019, & 022
ELECTRICAL PULSE WIDTH (MILLISECONDS)
PERCENT OF IMPULSE BIT AT EPW=10 MSEC
ORIGINAL PAGE IS OF POOR QUALITY

Figure 4-6

ORIGINAL PAGE IS
OF POOR QUALITY

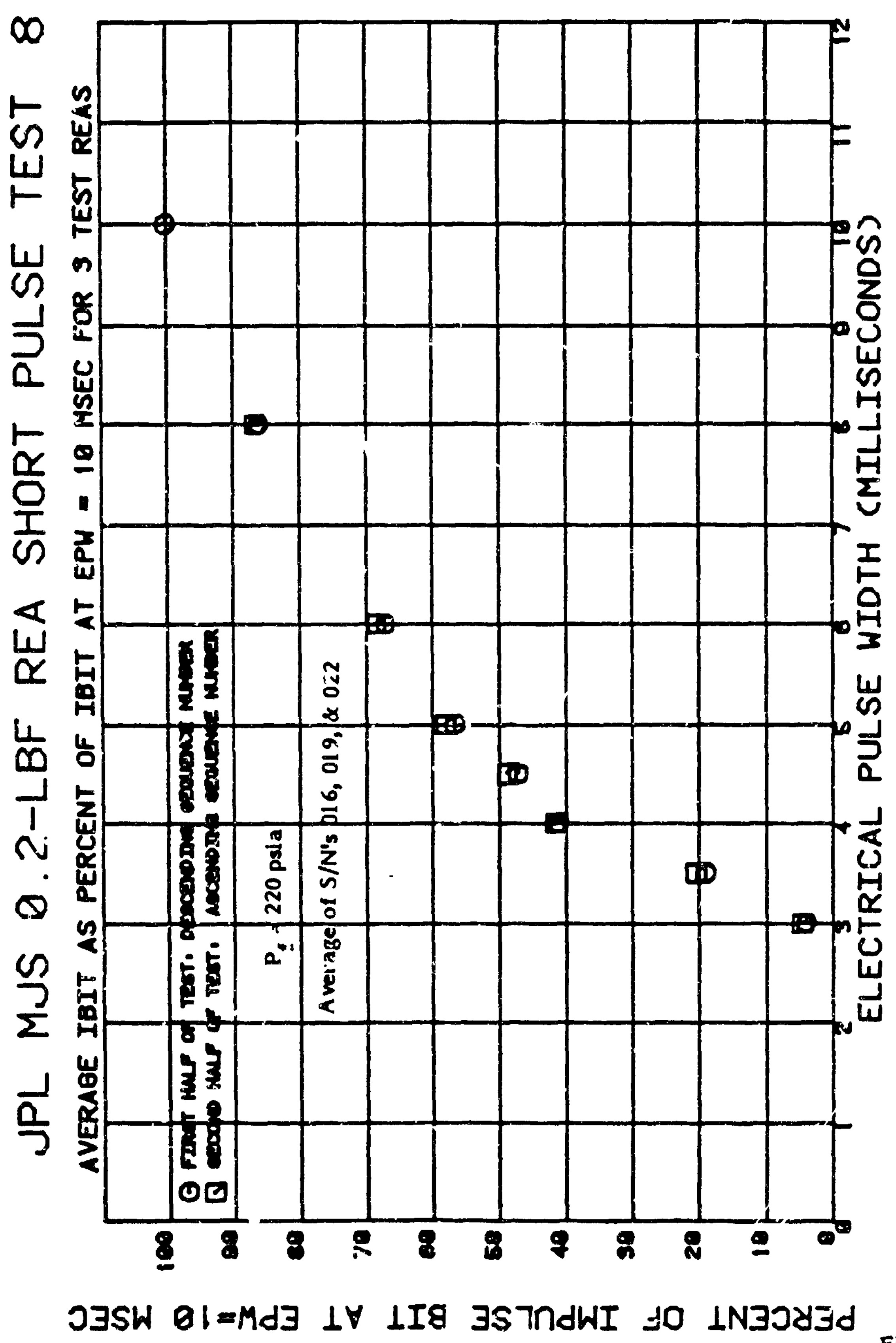
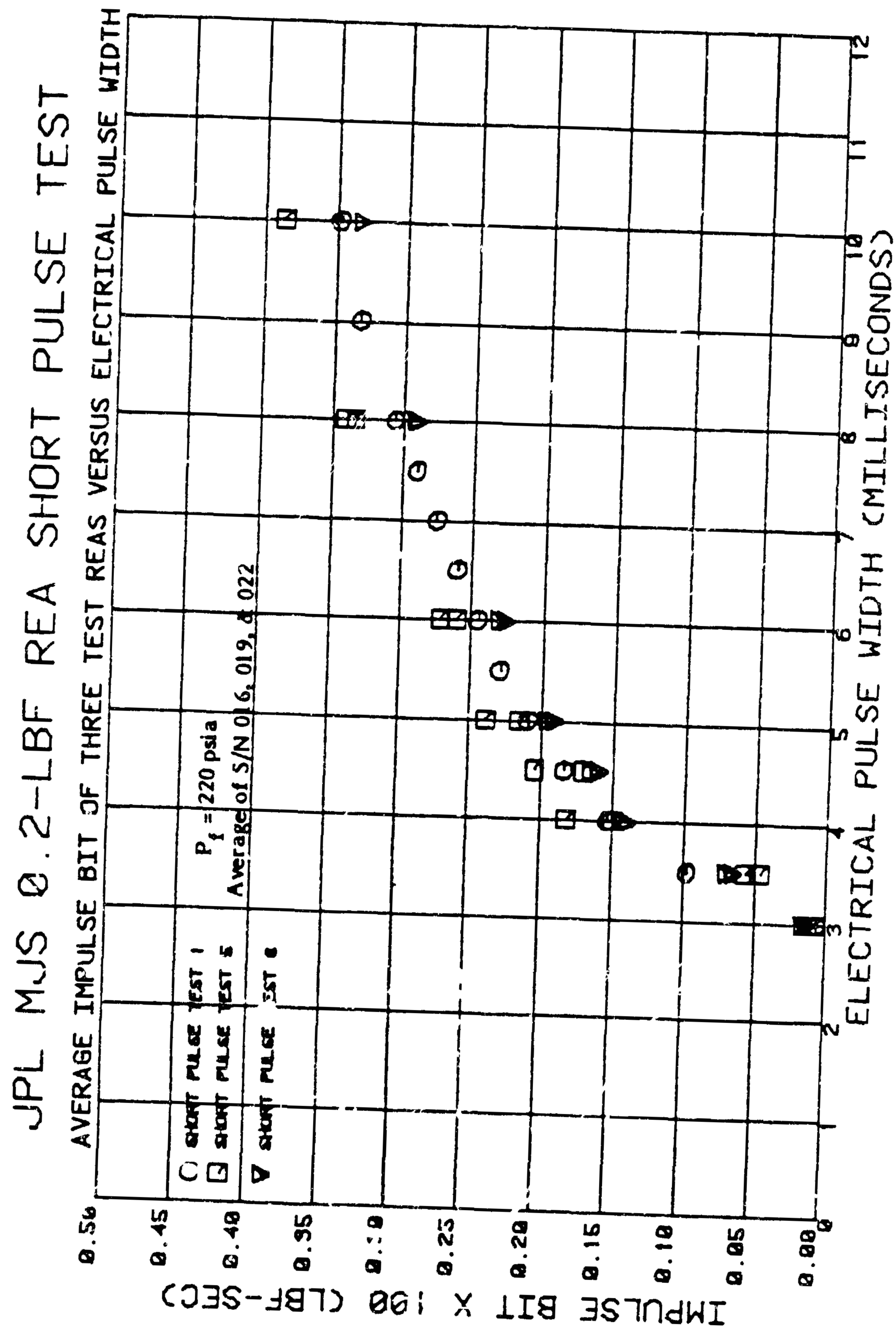


Figure 4-7



JPL MJS 0.2-LBF REA SHORT PULSE TEST
AVERAGE IMPULSE BIT OF THREE TEST REAS VERSUS ELECTRICAL PULSE WIDTH
SHORT PULSE TEST 1
SHORT PULSE TEST 5
SHORT PULSE EST 6
P_f = 220 psia
Average of S/N 016, 019, & 022
ELECTRICAL PULSE WIDTH (MILLISECONDS)
IMPULSE BIT X 100 (LBF-SEC)
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0
2
3
4
5
6
7
8
9
10
11
12

Figure 4-8

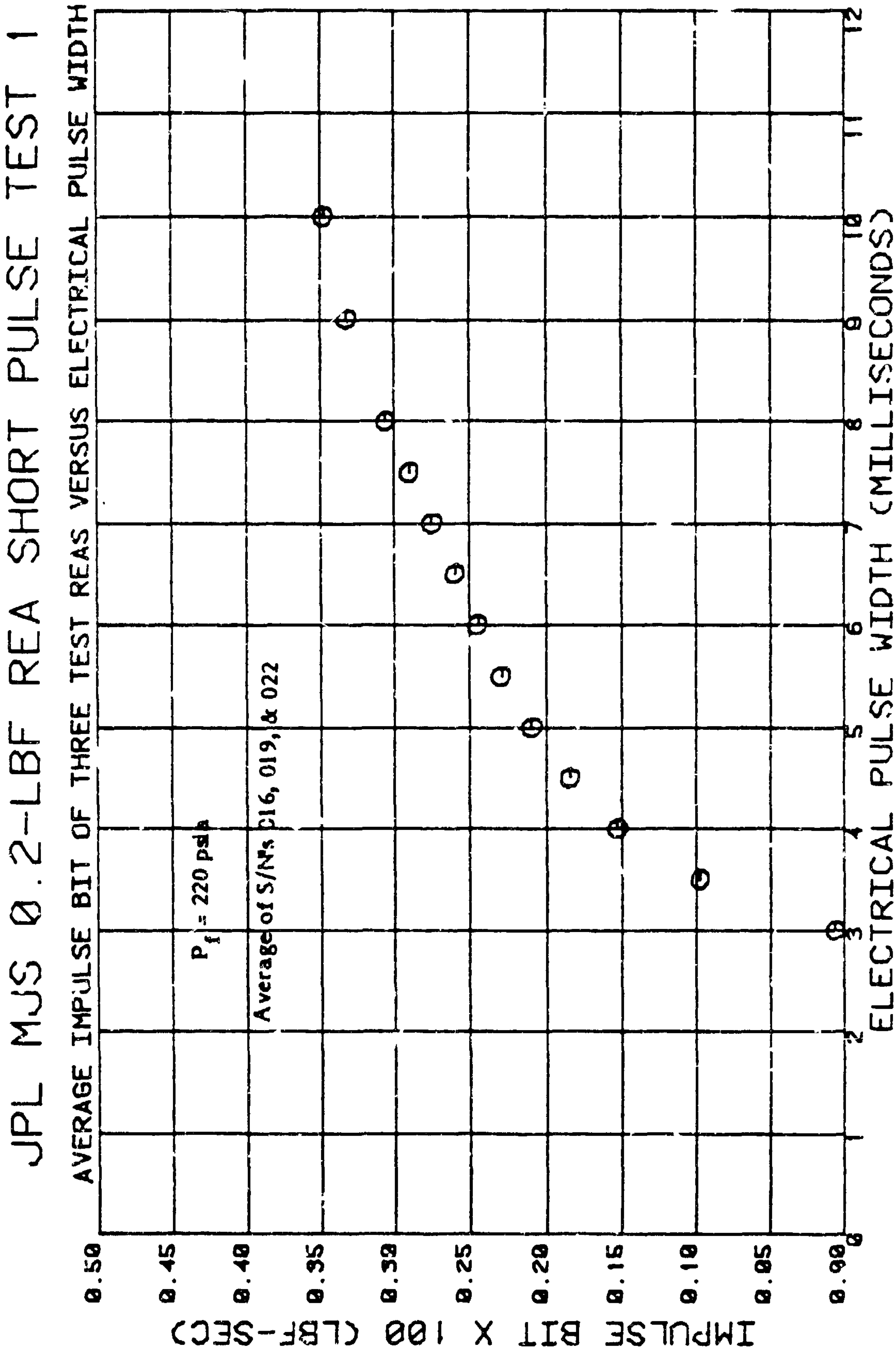

JPL MJS 0.2-LBF REA SHORT PULSE TEST 1
AVERAGE IMPULSE BIT OF THREE TEST REAS VERSUS ELECTRICAL PULSE WIDTH
P_f = 220 psia
Average of S/N's 016, 019, & 022
ELECTRICAL PULSE WIDTH (MILLISECONDS)
IMPULSE BIT X 100 (LBF-SEC)
0 1 2 3 4 5 6 7 8 9 10 11 12
0.00 0.05 0.10 0.15 0.20 0.25 0.30 0.35 0.40 0.45 0.50

Figure 4-9

JPL MJS 0.2-LBF REA SHORT PULSE TEST 2

AVERAGE IMPULSE BIT OF THREE TEST REAS VERSUS ELECTRICAL PULSE WIDTH

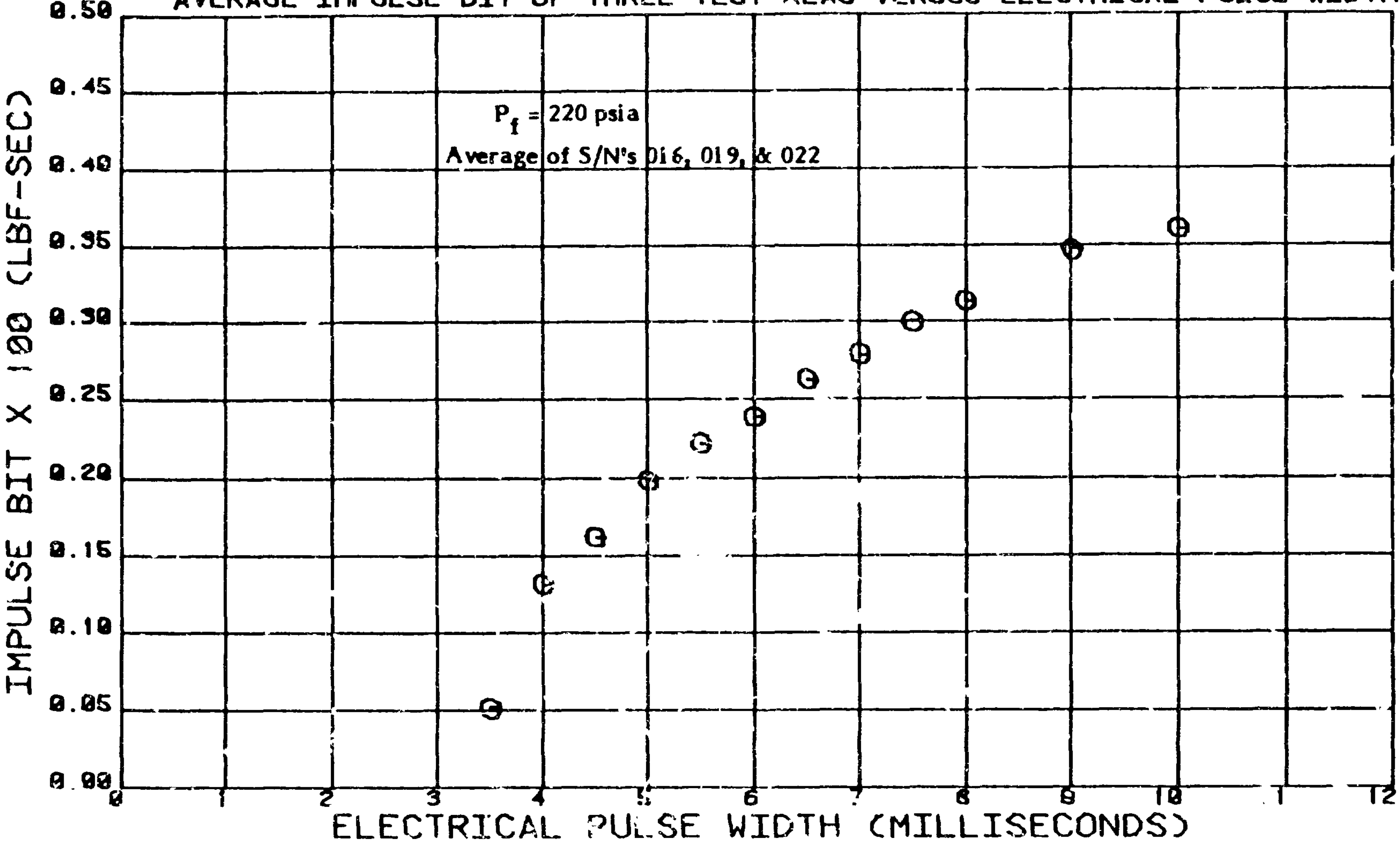


Figure 4-10

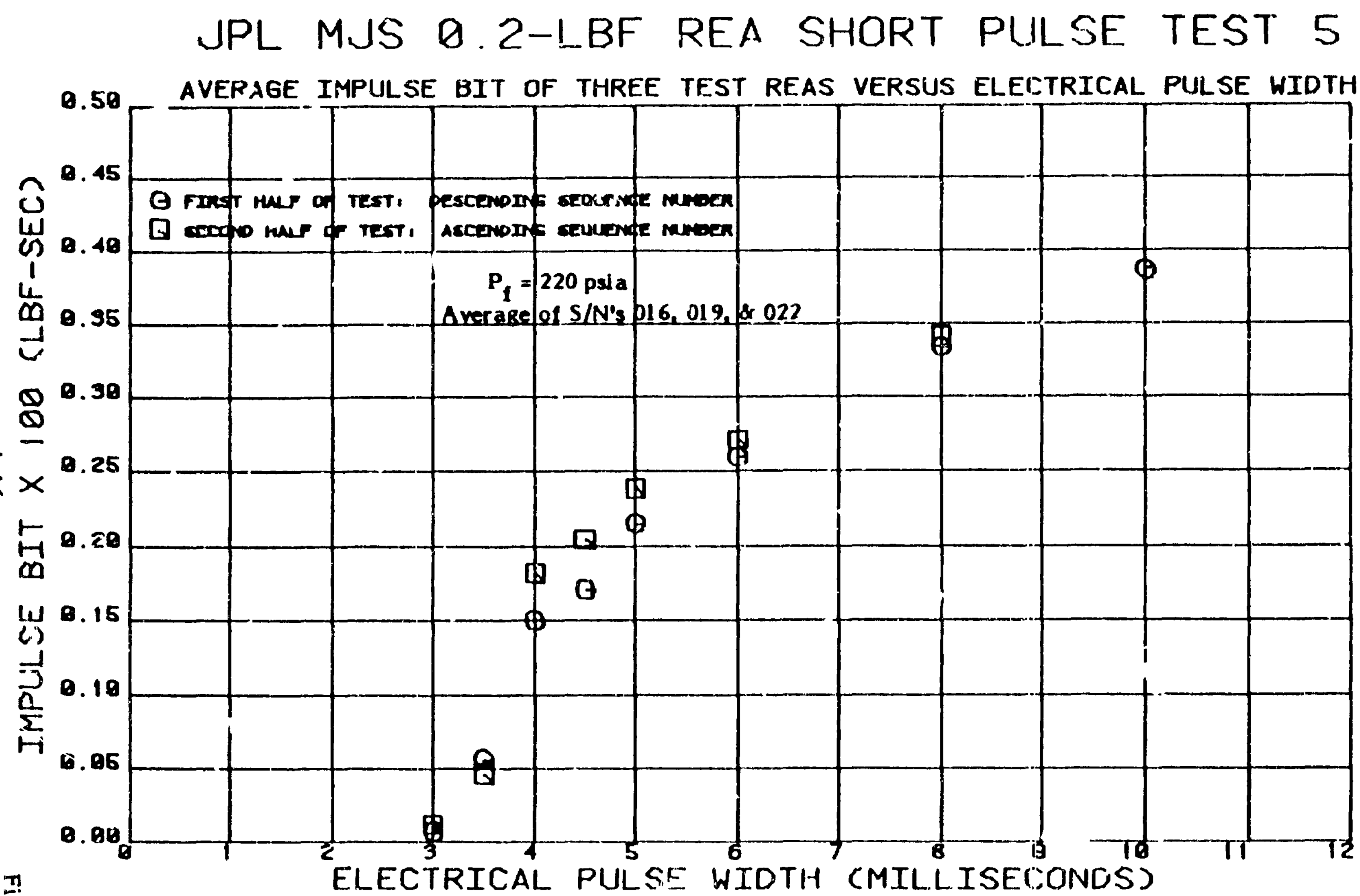

JPL MJS 0.2-LBF REA SHORT PULSE TEST 5
AVERAGE IMPULSE BIT OF THREE TEST REAS VERSUS ELECTRICAL PULSE WIDTH
FIRST HALF OF TEST: DESCENDING SEQUENCE NUMBER
SECOND HALF OF TEST: ASCENDING SEQUENCE NUMBER
P_f = 220 psia
Average of S/N's 016, 019, & 022
IMPULSE BIT X 100 (LBF-SEC)
ELECTRICAL PULSE WIDTH (MILLISECONDS)
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
0.45
0.50
0
1
2
3
4
5
6
7
8
9
10
11
12

Figure 4-1[illegible]

(4)

ORIGINAL PAGE IS
OF POOR QUALITY

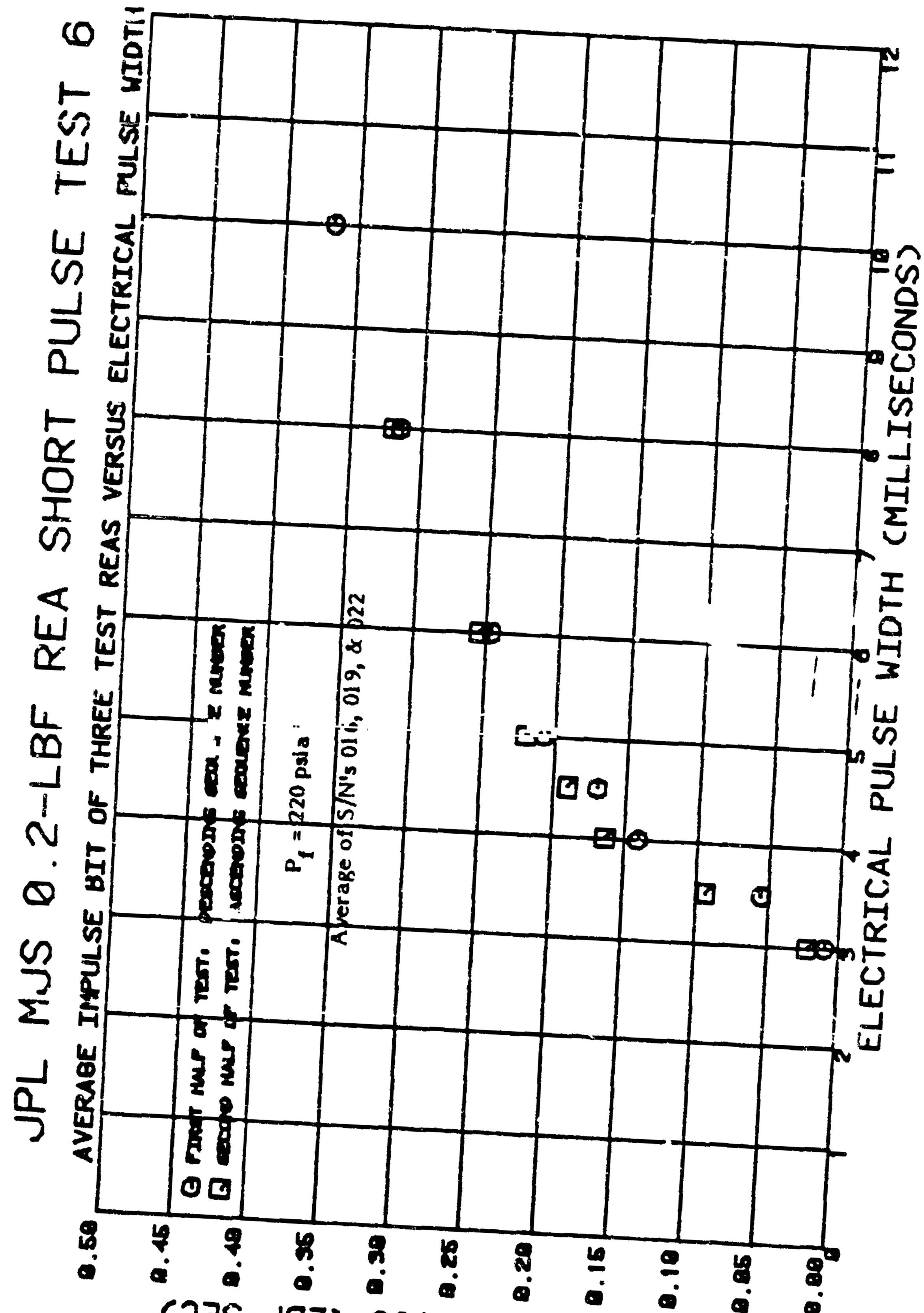


Figure 4-12

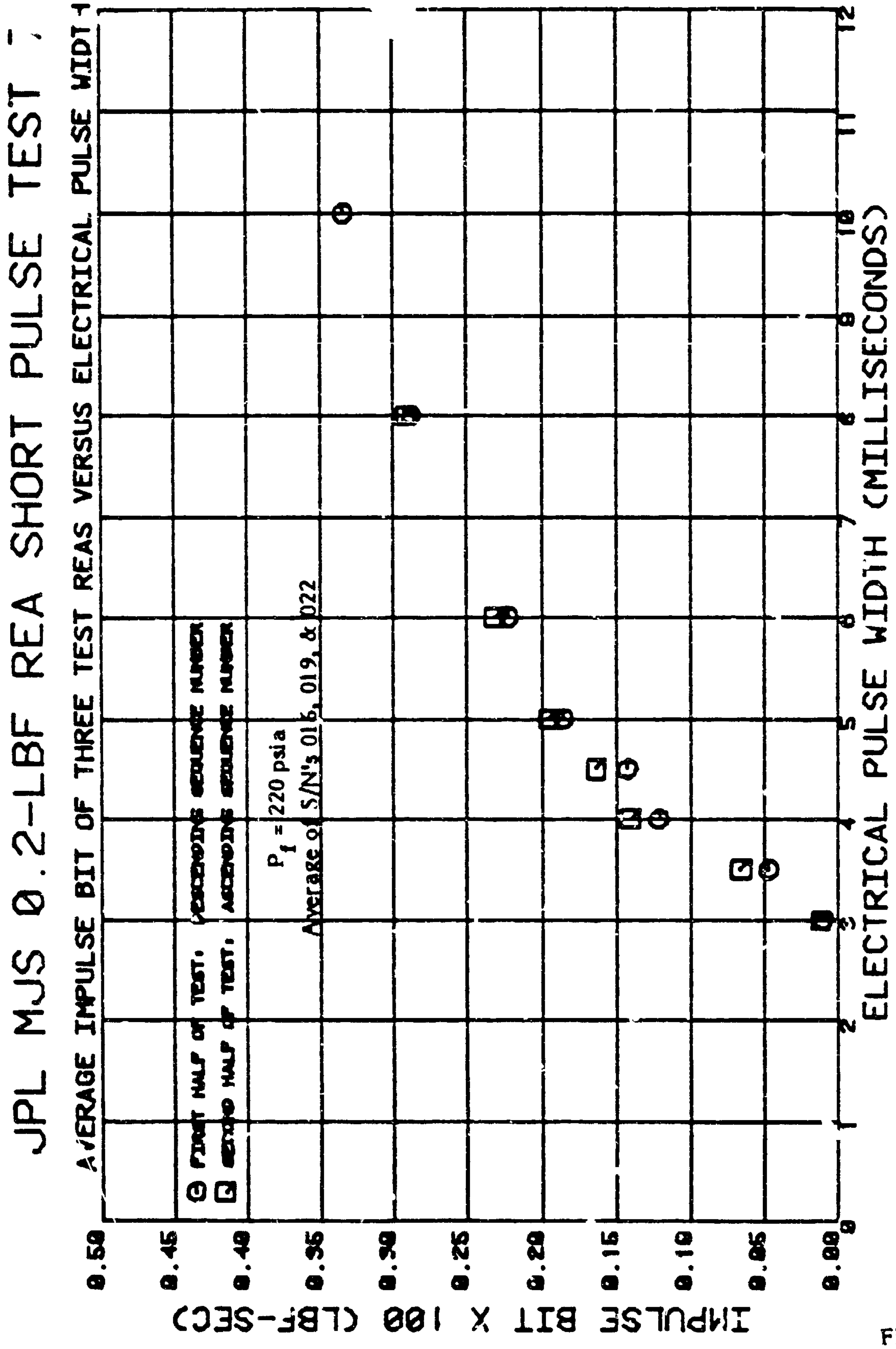

JPL MJS 0.2-LBF REA SHORT PULSE TEST 7
AVERAGE IMPULSE BIT OF THREE TEST REAS VERSUS ELECTRICAL PULSE WIDTH
FIRST HALF OF TEST, DESCENDING SEQUENCE NUMBER
SECOND HALF OF TEST, ASCENDING SEQUENCE NUMBER
P_f = 220 psia
Average of S/N's 016, 019, & 022
ELECTRICAL PULSE WIDTH (MILLISECONDS)
IMPULSE BIT X 100 (LBF-SEC)

Figure 4-13

ORIGINAL PAGE IS
OF POOR QUALITY

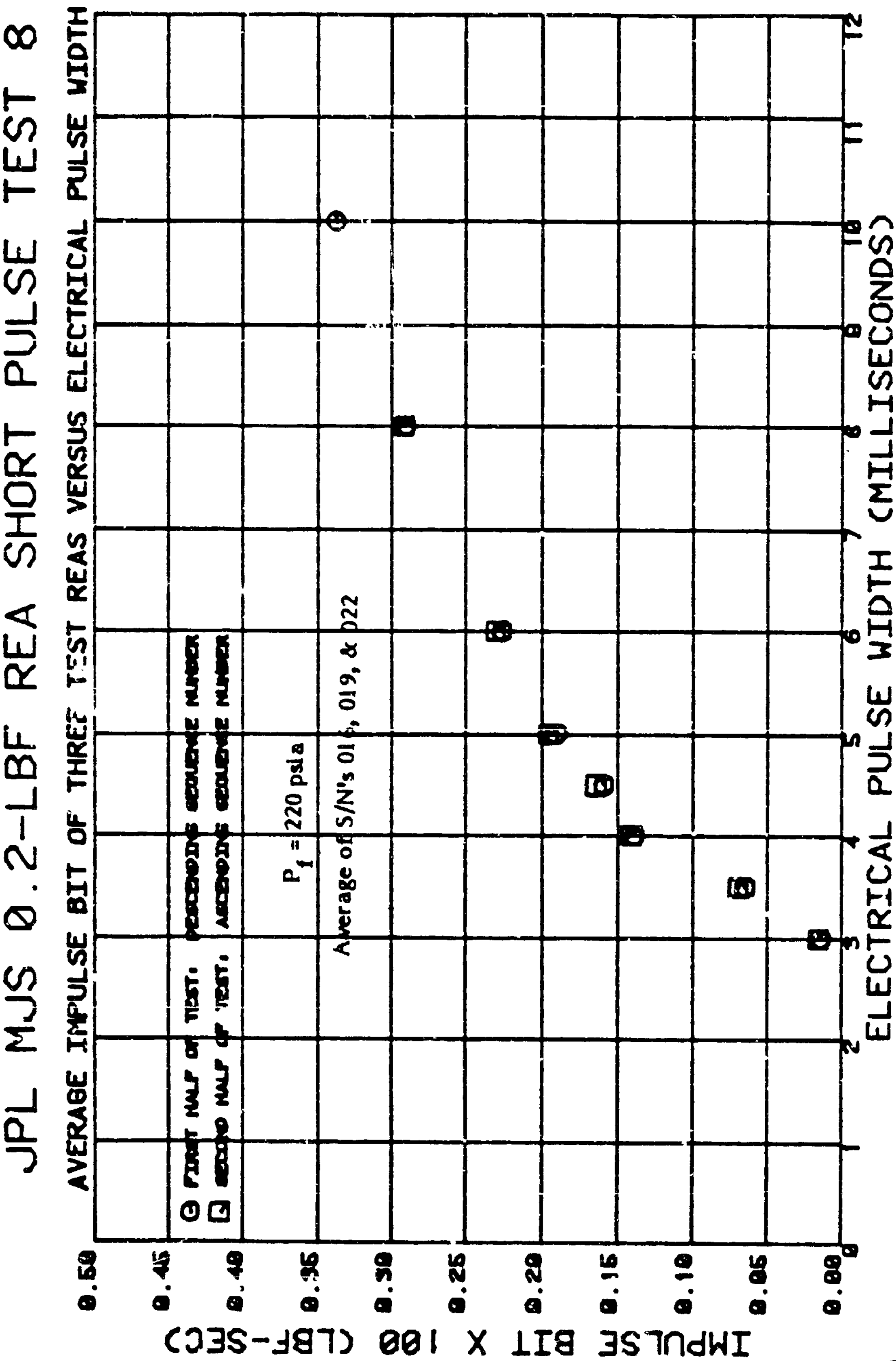
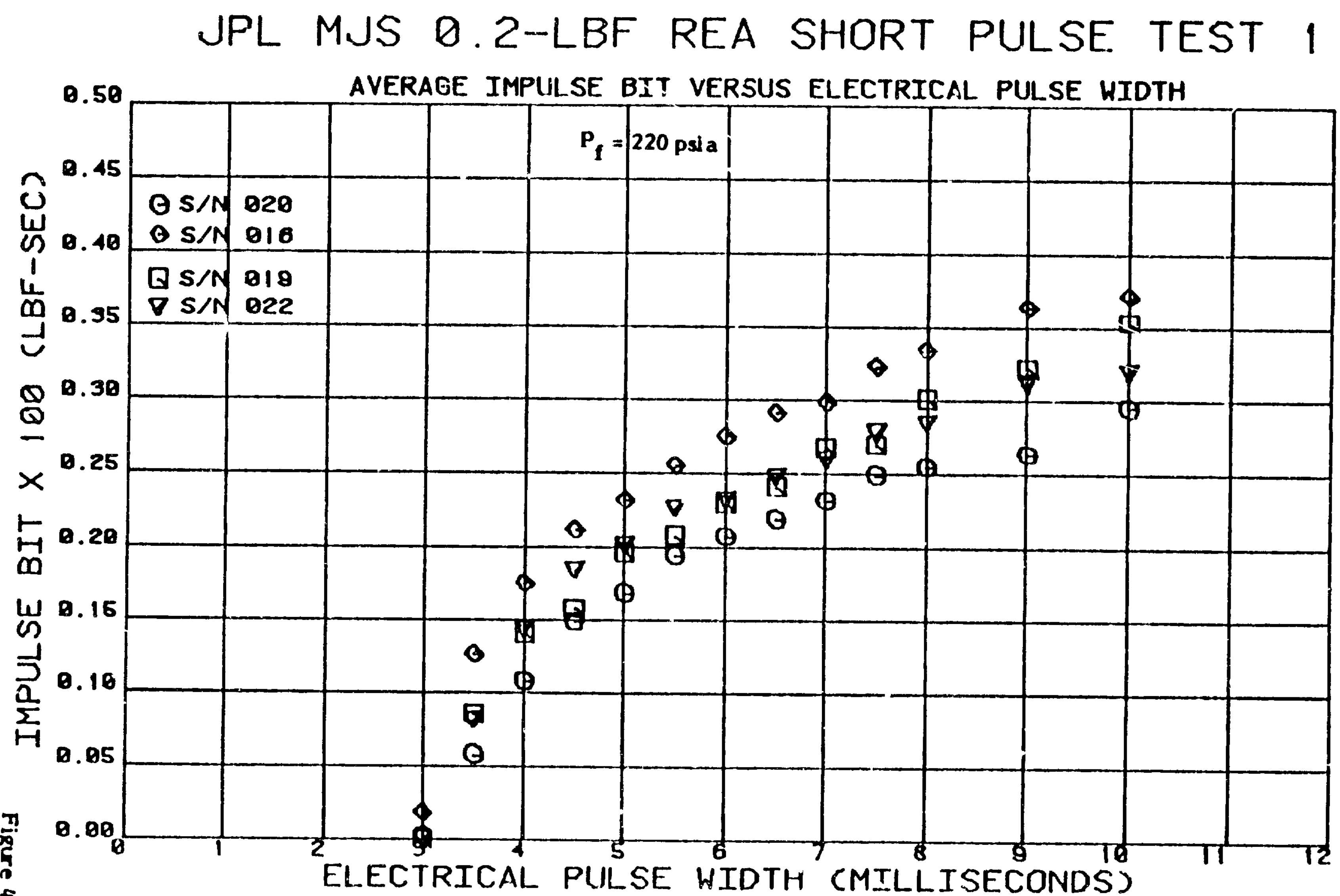


Figure 4-14



JPL MJS 0.2-LBF REA SHORT PULSE TEST 1
AVERAGE IMPULSE BIT VERSUS ELECTRICAL PULSE WIDTH
P_f = 220 psia
S/N 020
S/N 016
S/N 019
S/N 022
IMPULSE BIT X 100 (LBF-SEC)
ELECTRICAL PULSE WIDTH (MILLISECONDS)
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0
1
2
3
4
5
6
7
8
9
10
11
12

Figure 4-15

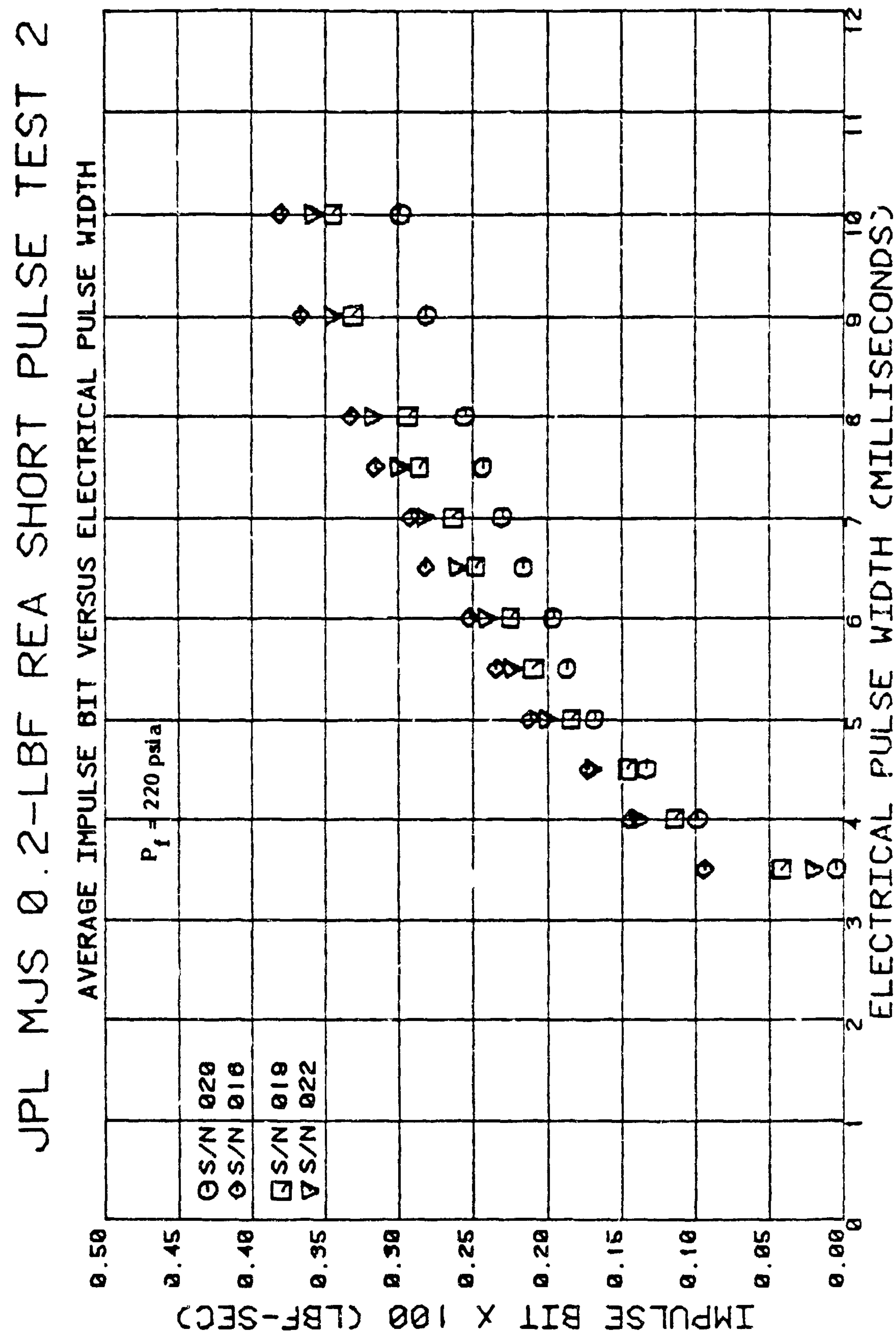

JPL MJS 0.2-LBF REA SHORT PULSE TEST 2
AVERAGE IMPULSE BIT VERSUS ELECTRICAL PULSE WIDTH
S/N 020
S/N 016
S/N 019
S/N 022
P_f = 220 psia
IMPULSE BIT X 100 (LBF-SEC)
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
0.45
0.50
ELECTRICAL PULSE WIDTH (MILLISECONDS)
0
1
2
3
4
5
6
7
8
9
10
11
12

Figure 4-16

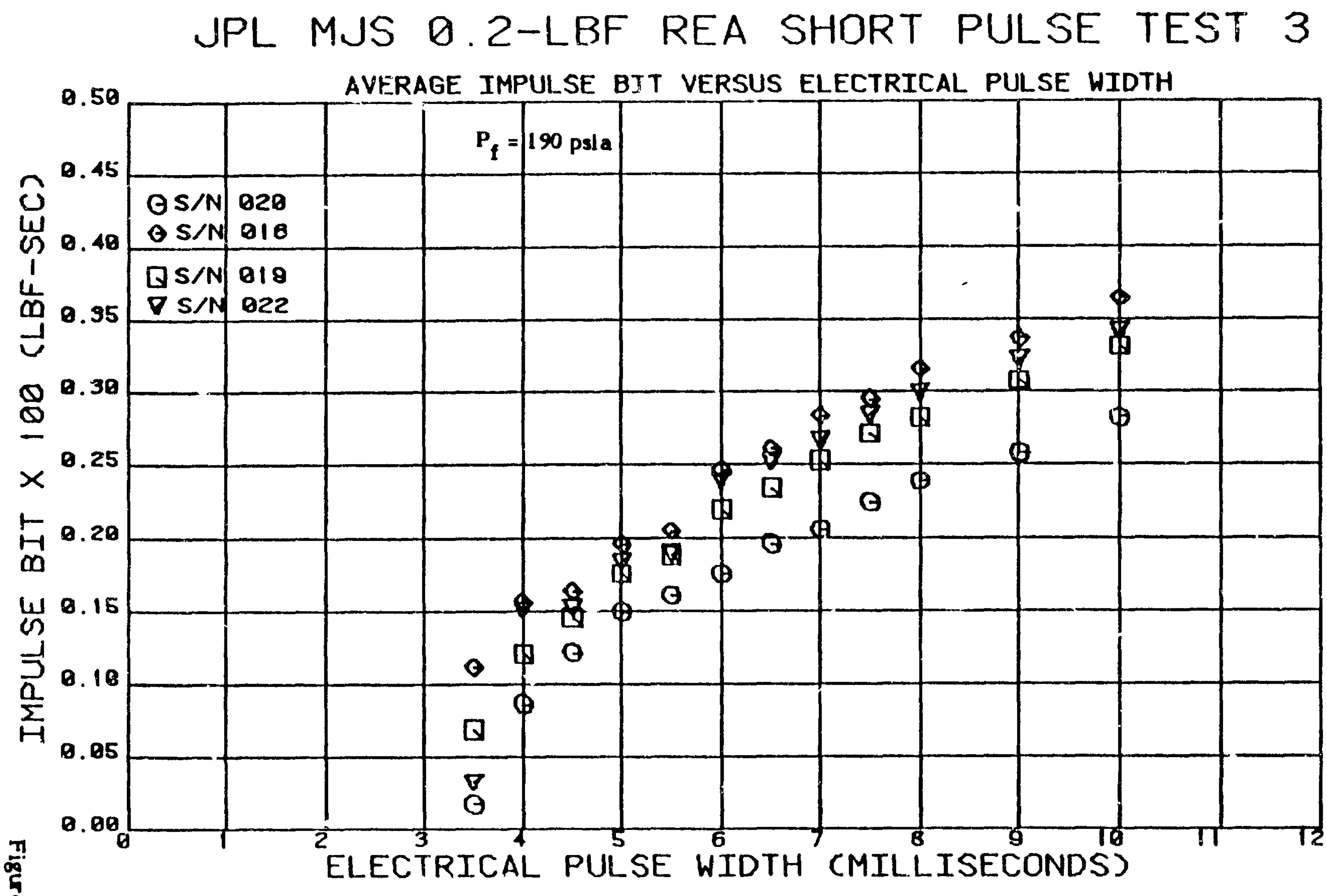
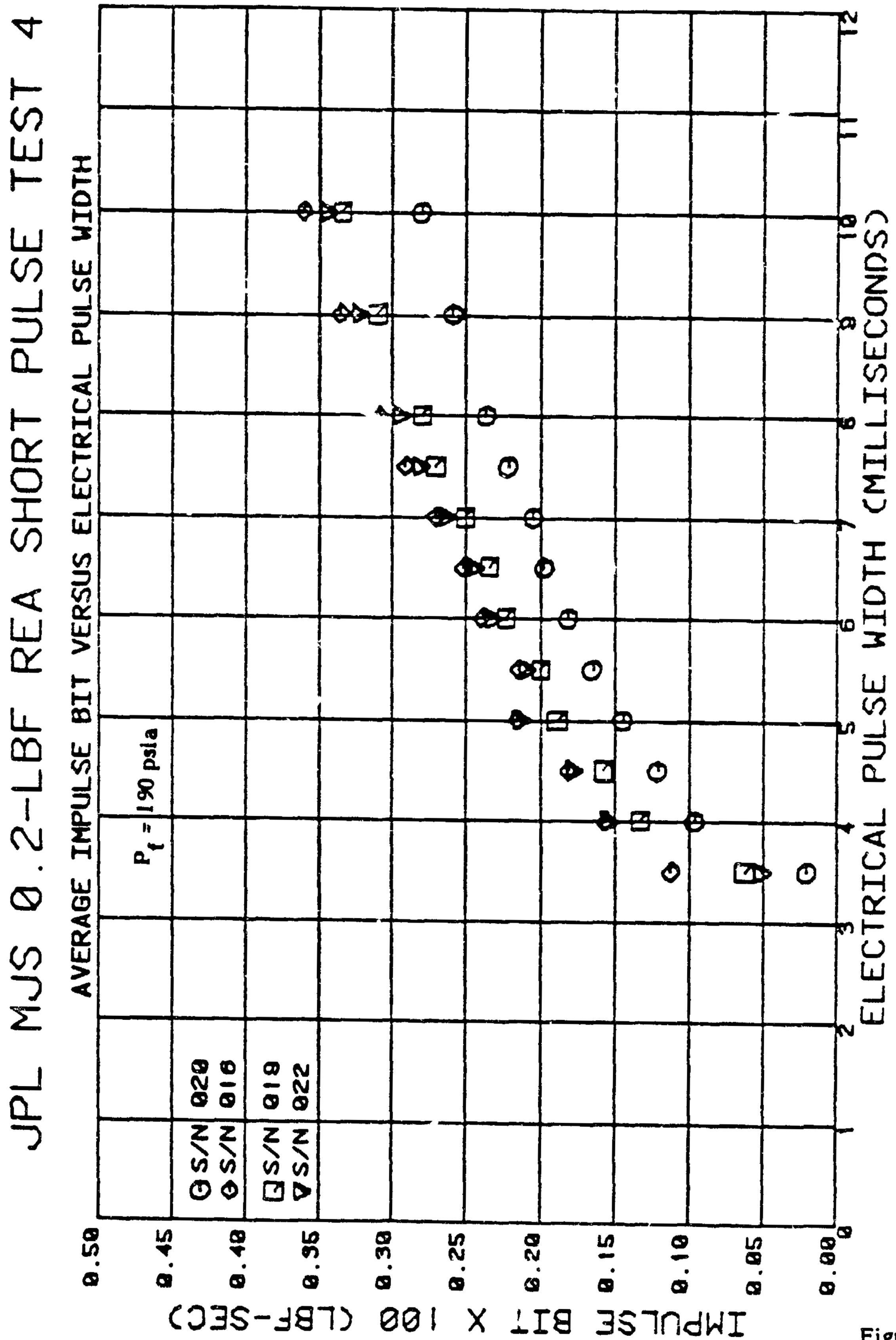
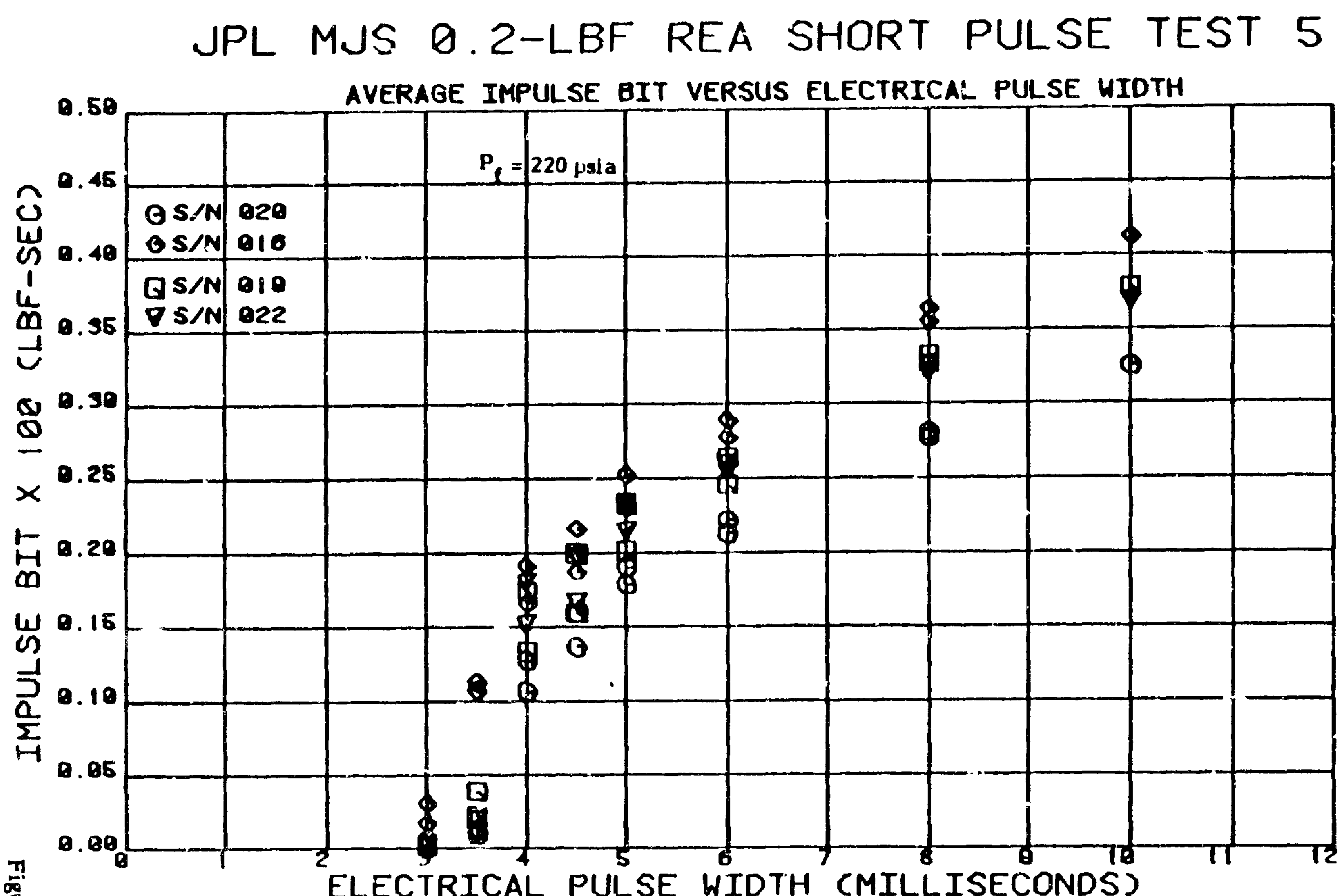

JPL MJS 0.2-LBF REA SHORT PULSE TEST 3
AVERAGE IMPULSE BIT VERSUS ELECTRICAL PULSE WIDTH
P_f = 190 psia
S/N 020
S/N 016
S/N 019
S/N 022
IMPULSE BIT X 100 (LBF-SEC)
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
0.45
0.50
ELECTRICAL PULSE WIDTH (MILLISECONDS)
0
1
2
3
4
5
6
7
8
9
10
11
12

Figure 4-17



JPL MJS 0.2-LBF REA SHORT PULSE TEST 4
AVERAGE IMPULSE BIT VERSUS ELECTRICAL PULSE WIDTH
P_f = 190 psia
S/N 020
S/N 016
S/N 019
S/N 022
IMPULSE BIT X 100 (LBF-SEC)
ELECTRICAL PULSE WIDTH (MILLISECONDS)
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
0.45
0.50
0
1
2
3
4
5
6
7
8
9
10
11
12

Figure 4-18



JPL MJS 0.2-LBF REA SHORT PULSE TEST 5
AVERAGE IMPULSE BIT VERSUS ELECTRICAL PULSE WIDTH
P_f = 220 psia
S/N 020
S/N 016
S/N 019
S/N 022
IMPULSE BIT X 100 (LBF-SEC)
ELECTRICAL PULSE WIDTH (MILLISECONDS)
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0
1
2
3
4
5
6
7
8
9
10
11
12

Figure 4-19

ORIGINAL PAGE
OF POOR QUALITY

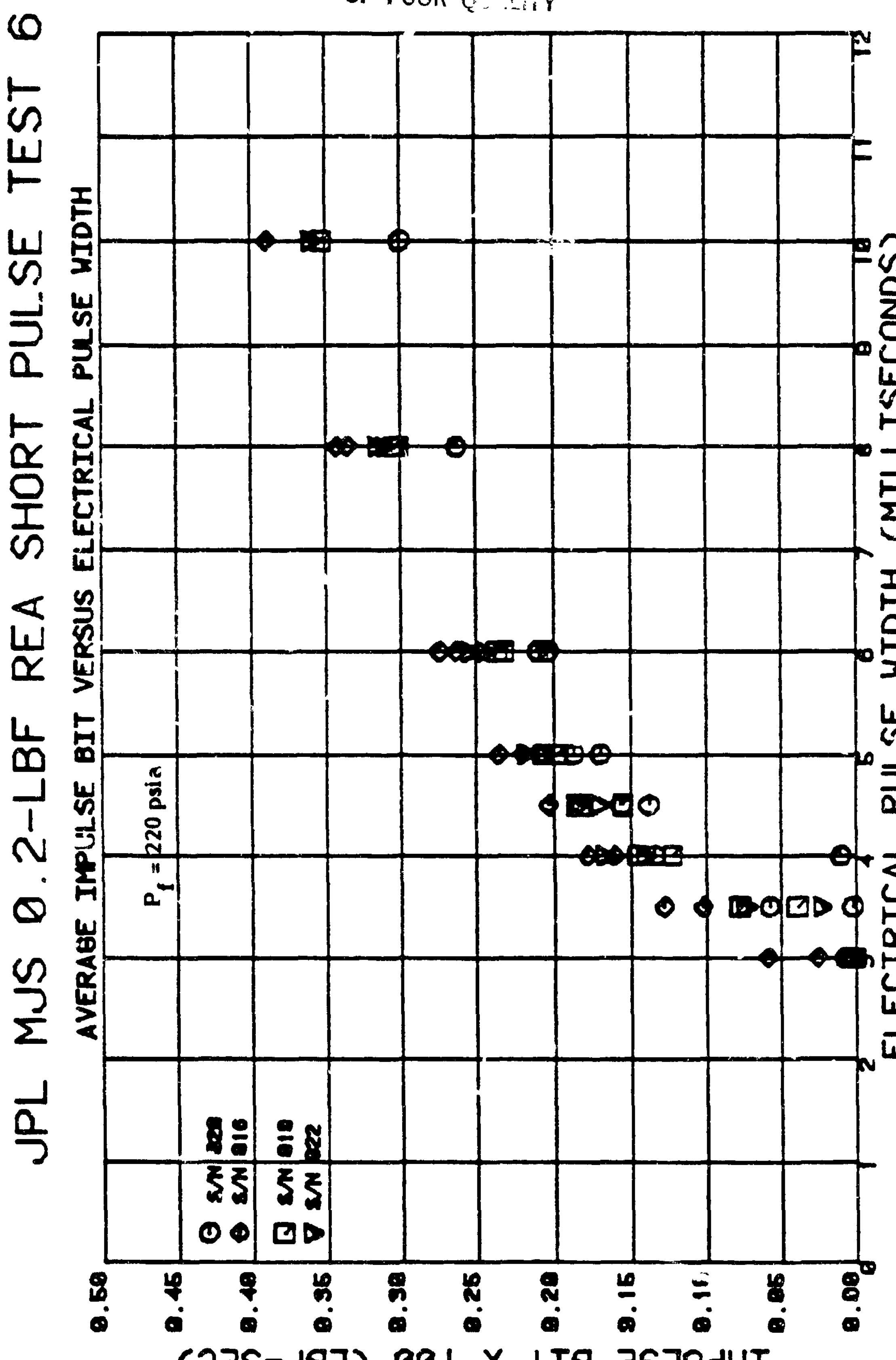


Figure 4-20

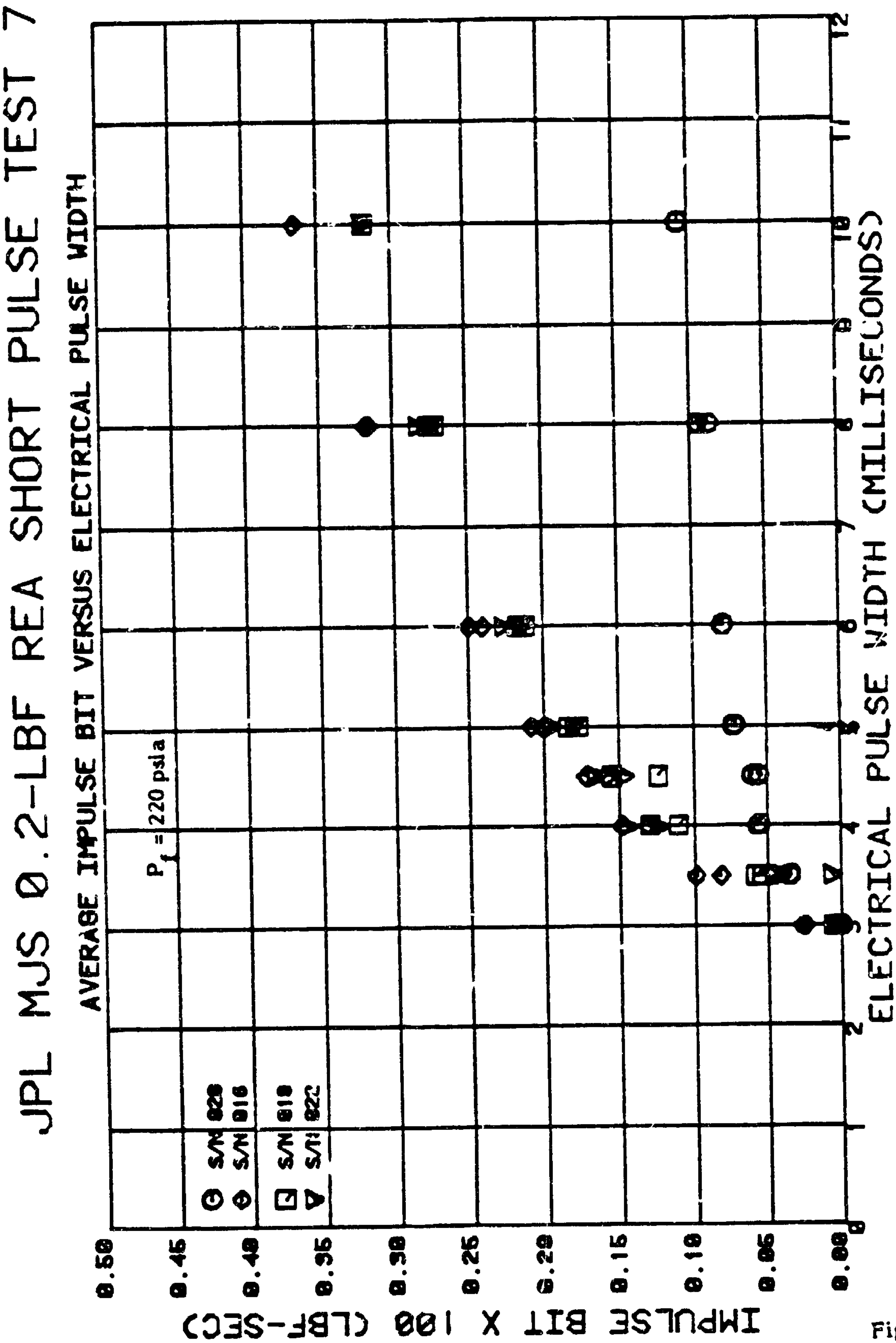

JPL MJS 0.2-LBF REA SHORT PULSE TEST 7
AVERAGE IMPULSE BIT VERSUS ELECTRICAL PULSE WIDTH
P_f = 220 psia
S/N 020
S/N 016
S/N 018
S/N 022
IMPULSE BIT X 100 (LBF-SEC)
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
ELECTRICAL PULSE WIDTH (MILLISECONDS)
0
1
2
3
4
5
6
7
8
9
10
11
12

Figure 4-21

ORIGINAL PAGE IS OF POOR QUALITY

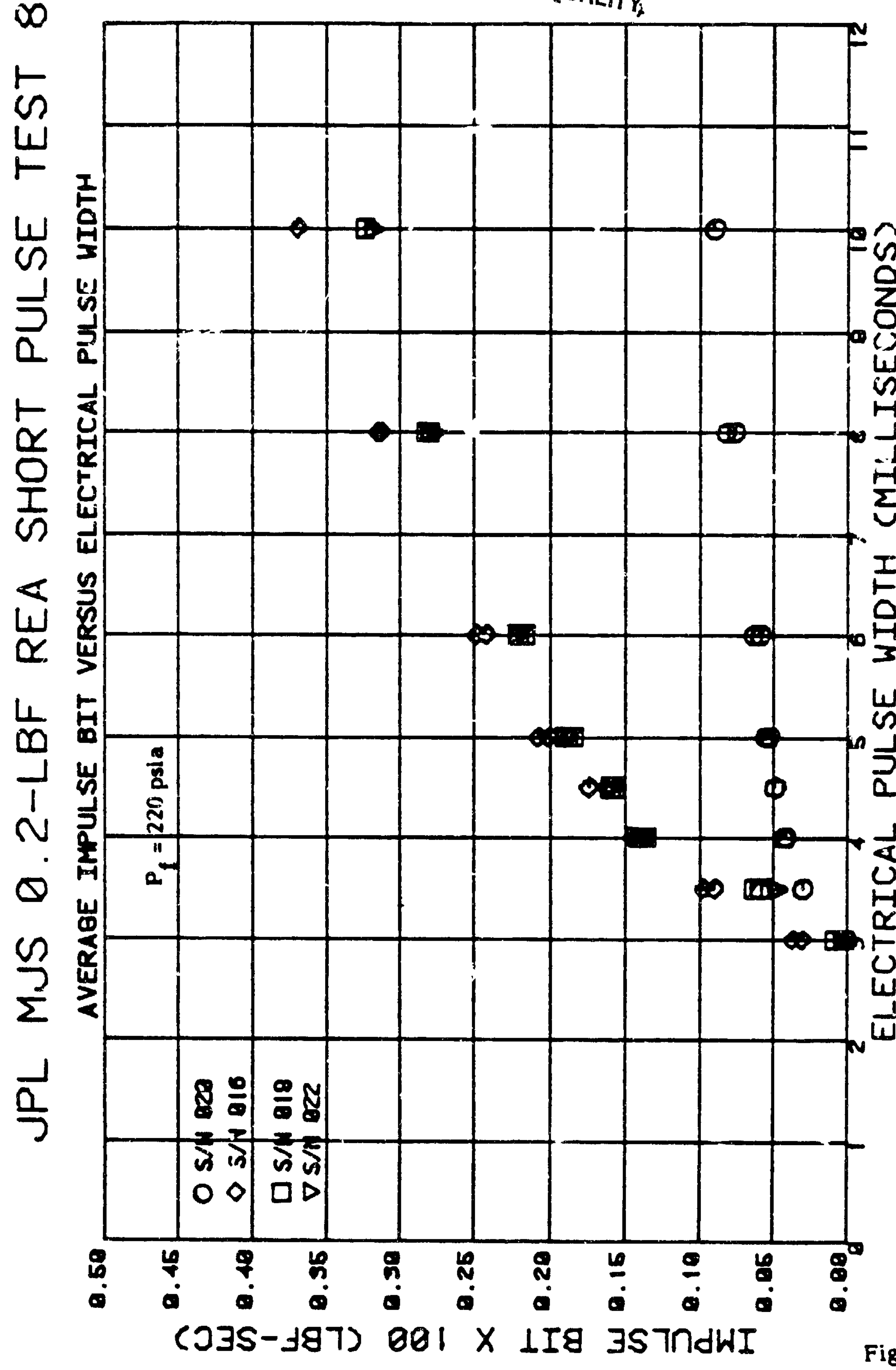


Figure 4-22

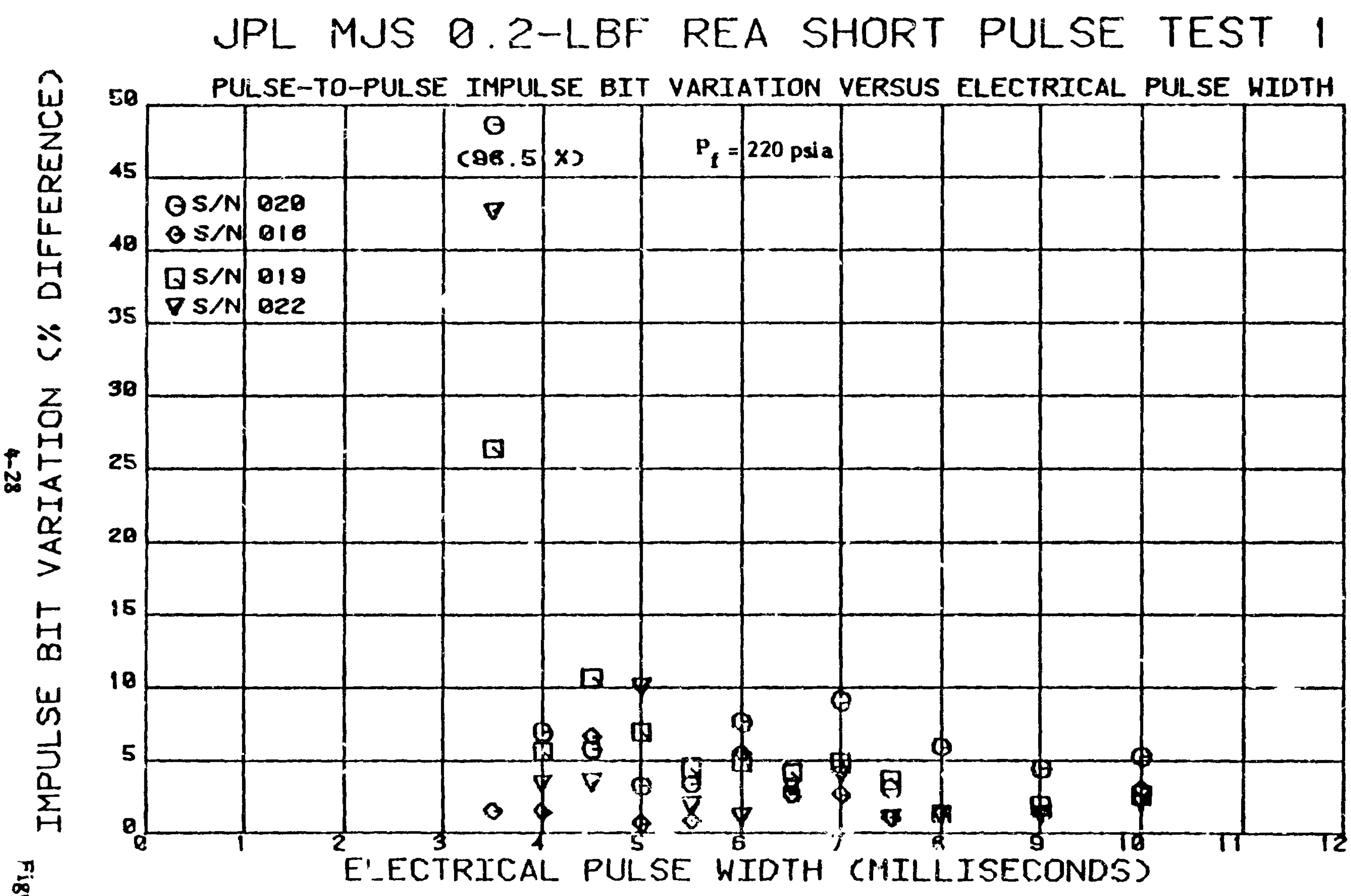

JPL MJS 0.2-LBF REA SHORT PULSE TEST 1
PULSE-TO-PULSE IMPULSE BIT VARIATION VERSUS ELECTRICAL PULSE WIDTH
(96.5 X)
P_f = 220 psia
S/N 020
S/N 016
S/N 019
S/N 022
IMPULSE BIT VARIATION (% DIFFERENCE)
ELECTRICAL PULSE WIDTH (MILLISECONDS)
0
5
10
15
20
25
30
35
40
45
50
0
1
2
3
4
5
6
7
8
9
10
11
12

Figure 4-23

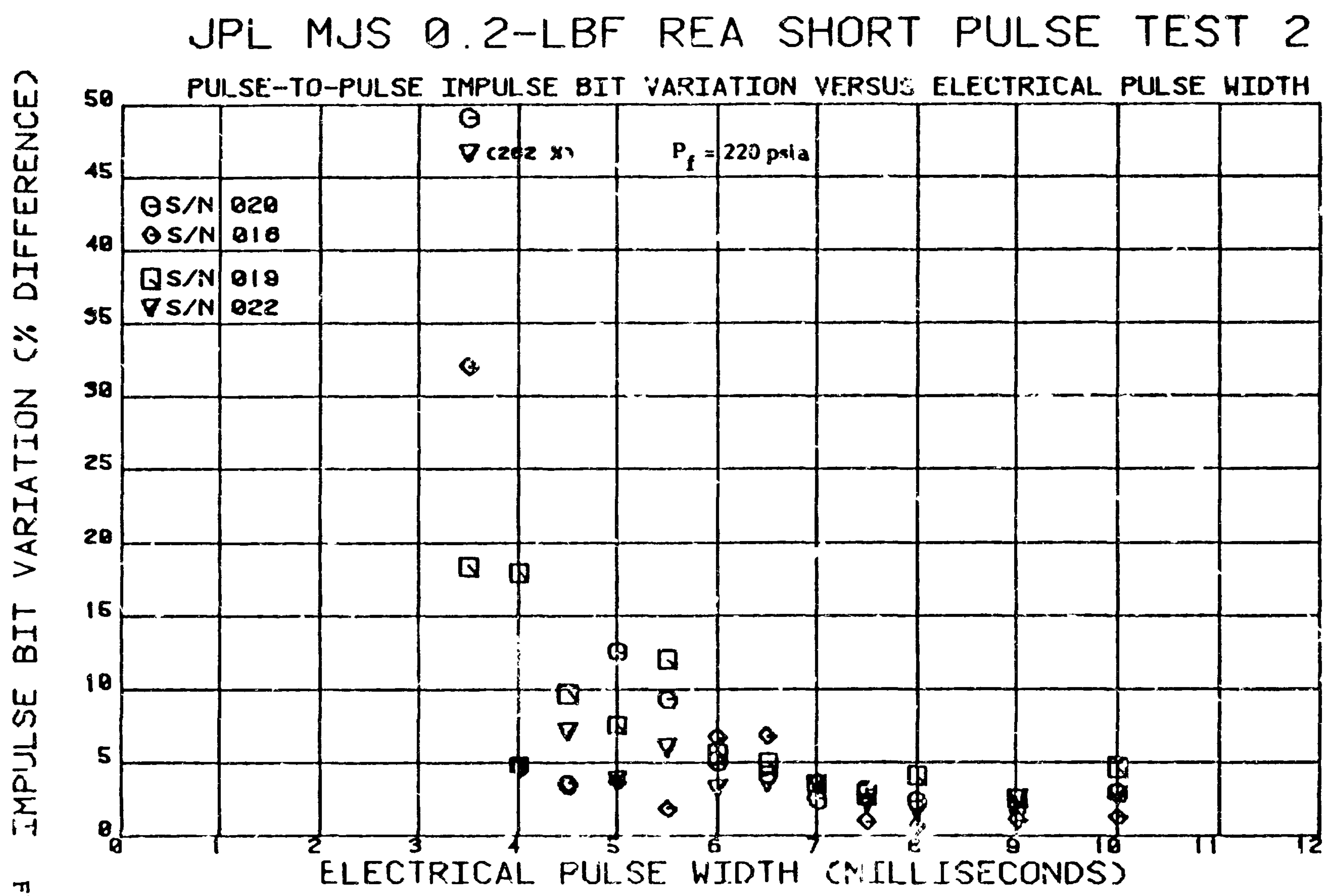

JPL MJS 0.2-LBF REA SHORT PULSE TEST 2
PULSE-TO-PULSE IMPULSE BIT VARIATION VERSUS ELECTRICAL PULSE WIDTH
S/N 020
S/N 016
S/N 019
S/N 022
P_f = 220 psia
IMPULSE BIT VARIATION (% DIFFERENCE)
ELECTRICAL PULSE WIDTH (MILLISECONDS)
0
5
10
15
20
25
30
35
40
45
50
0
1
2
3
4
5
6
7
8
9
10
11
12

Figure 4-24

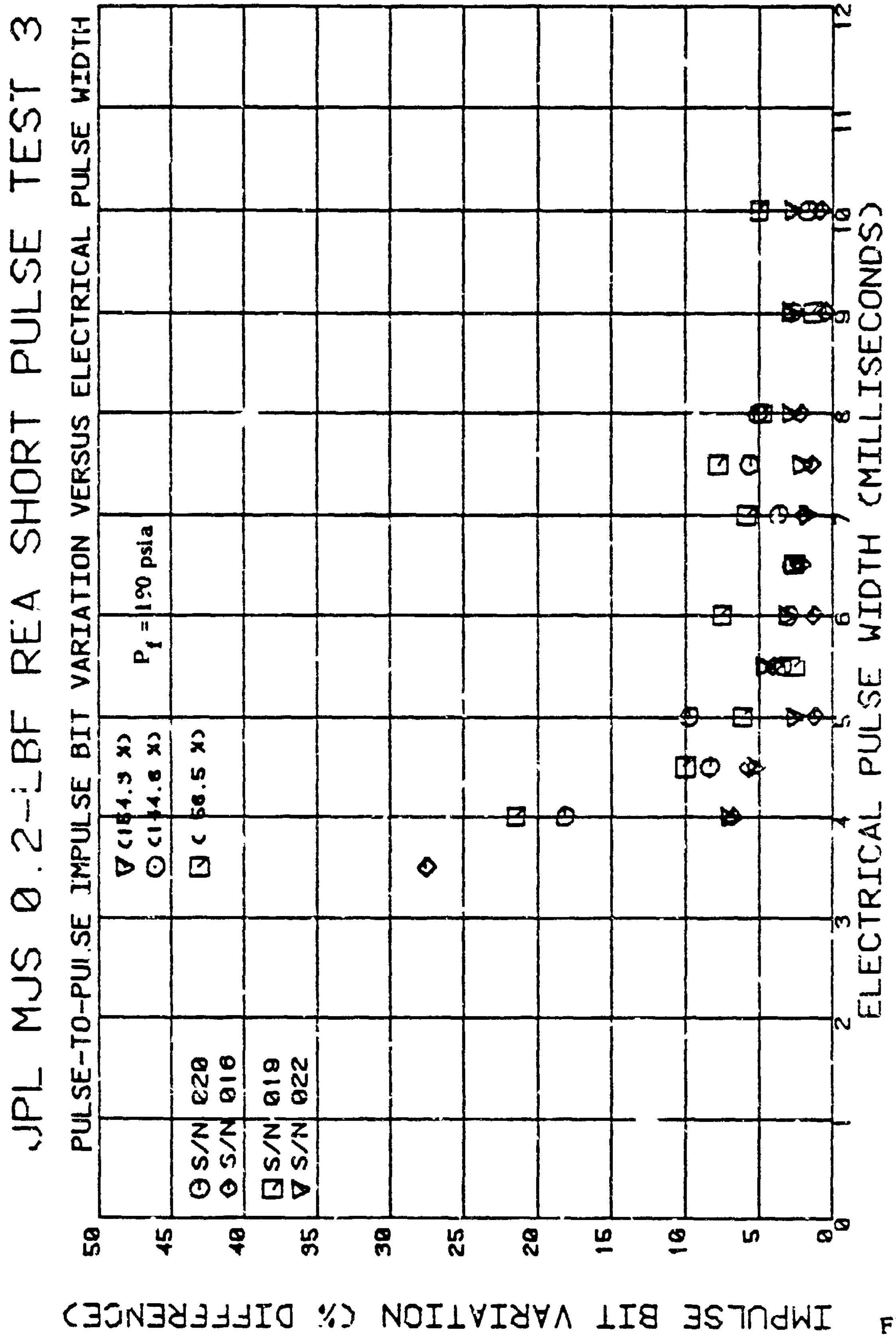
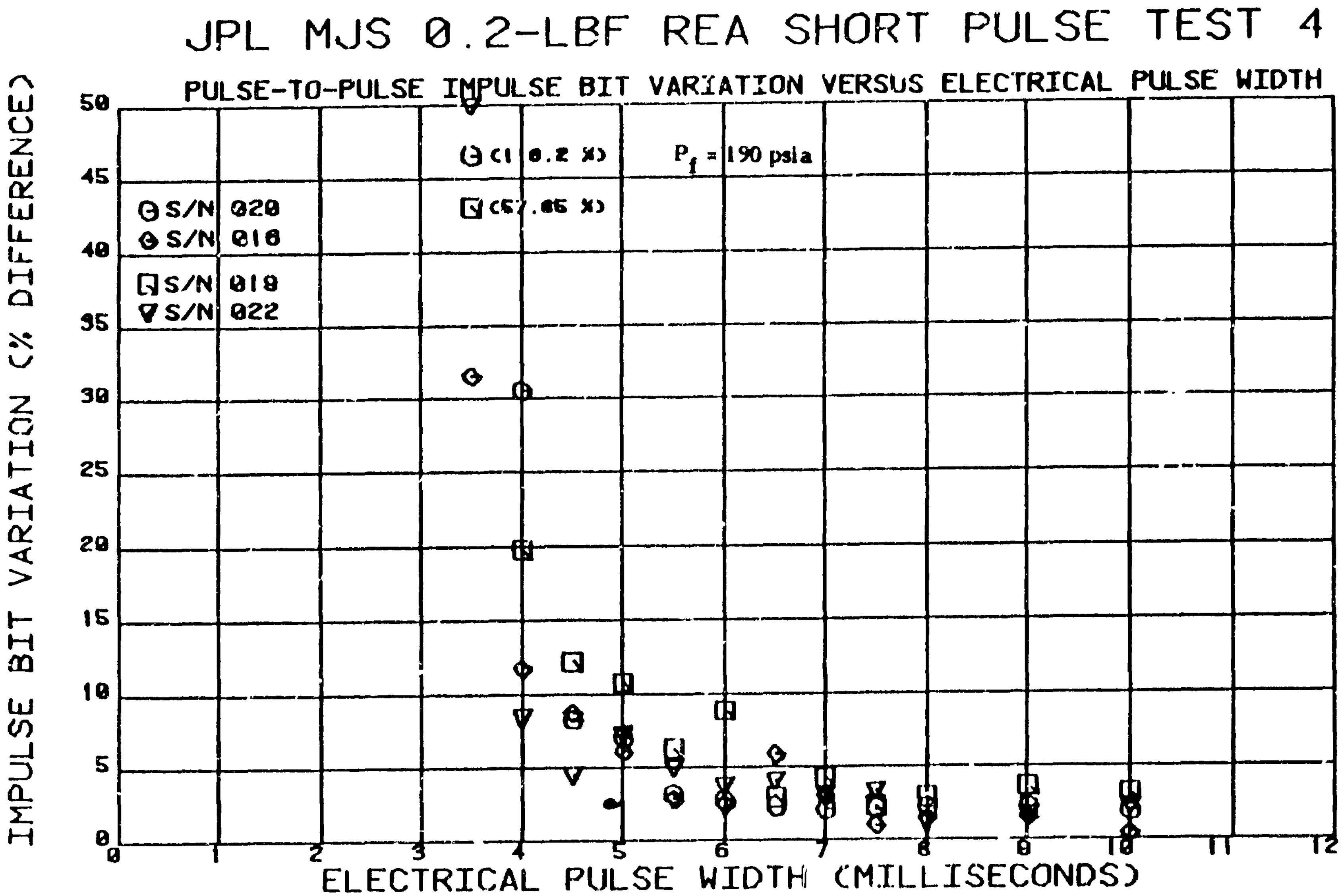

JPL MJS 0.2-LBF REA SHORT PULSE TEST 3
PULSE-TO-PULSE IMPULSE BIT VARIATION VERSUS ELECTRICAL PULSE WIDTH
S/N 020 (184.3 X)
S/N 018 (134.8 X)
S/N 019 (56.5 X)
S/N 022
P_f = 190 psia
ELECTRICAL PULSE WIDTH (MILLISECONDS)
IMPULSE BIT VARIATION (% DIFFERENCE)

Figure 4-25



ORIGINAL PAGE IS OF POOR QUALITY

Figure 4-26

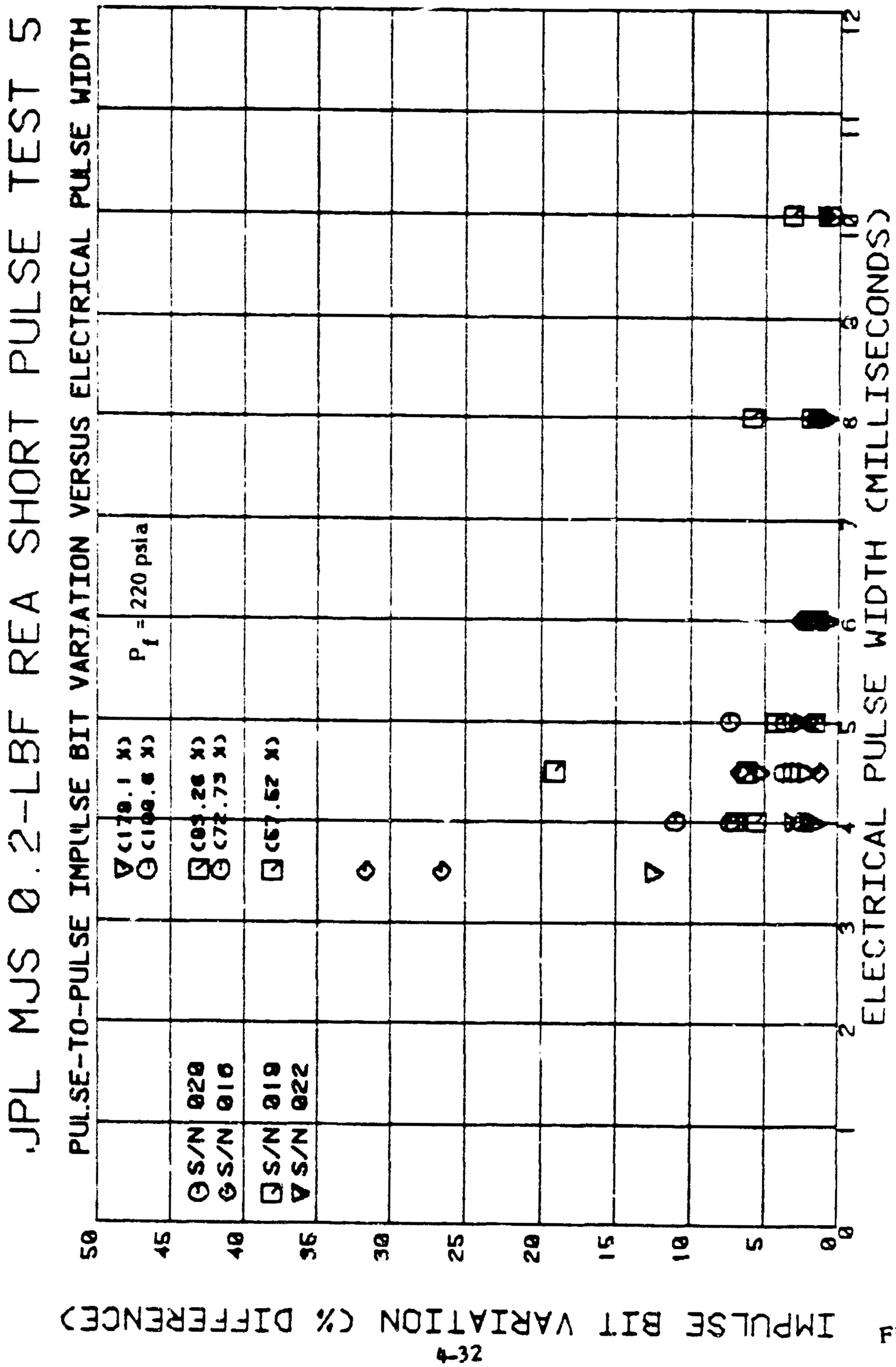

JPL MJS 0.2-LBF REA SHORT PULSE TEST 5
PULSE-TO-PULSE IMPULSE BIT VARIATION VERSUS ELECTRICAL PULSE WIDTH
S/N 020
S/N 010
S/N 019
S/N 022
(83.26 %)
(72.75 %)
(57.52 %)
P_f = 220 psia
ELECTRICAL PULSE WIDTH (MILLISECONDS)
IMPULSE BIT VARIATION (% DIFFERENCE)

Figure 4-27

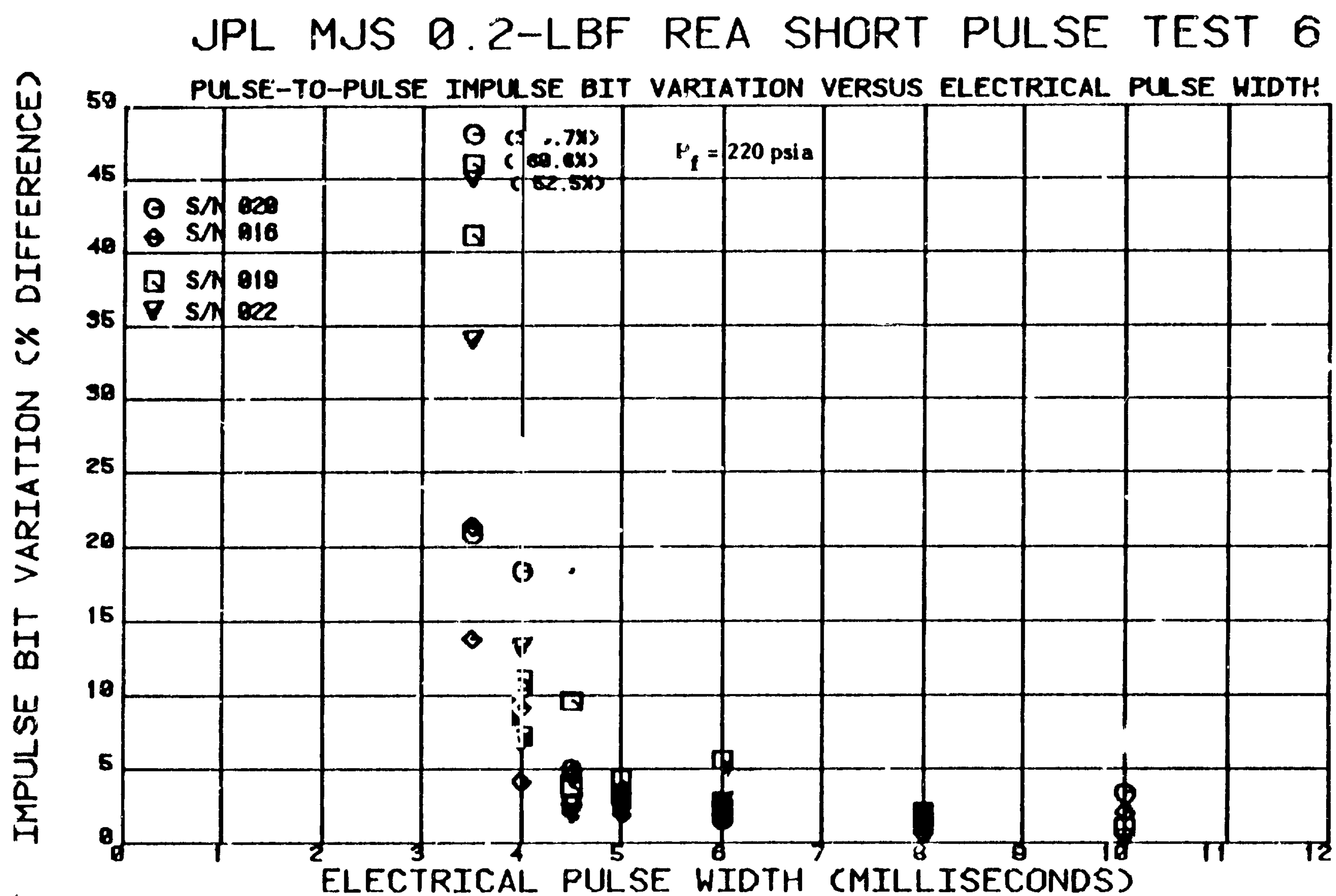

JPL MJS 0.2-LBF REA SHORT PULSE TEST 6
PULSE-TO-PULSE IMPULSE BIT VARIATION VERSUS ELECTRICAL PULSE WIDTH
P_f = 220 psia
S/N 020
S/N 016
S/N 019
S/N 022
(69.6%)
(52.5%)
IMPULSE BIT VARIATION (% DIFFERENCE)
ELECTRICAL PULSE WIDTH (MILLISECONDS)
0
5
10
15
20
25
30
35
40
45
50
1
2
3
4
5
6
7
8
9
10
11
12

Figure 4-28

JPL MJS 0.2-LBF REA SHORT PULSE TEST 7

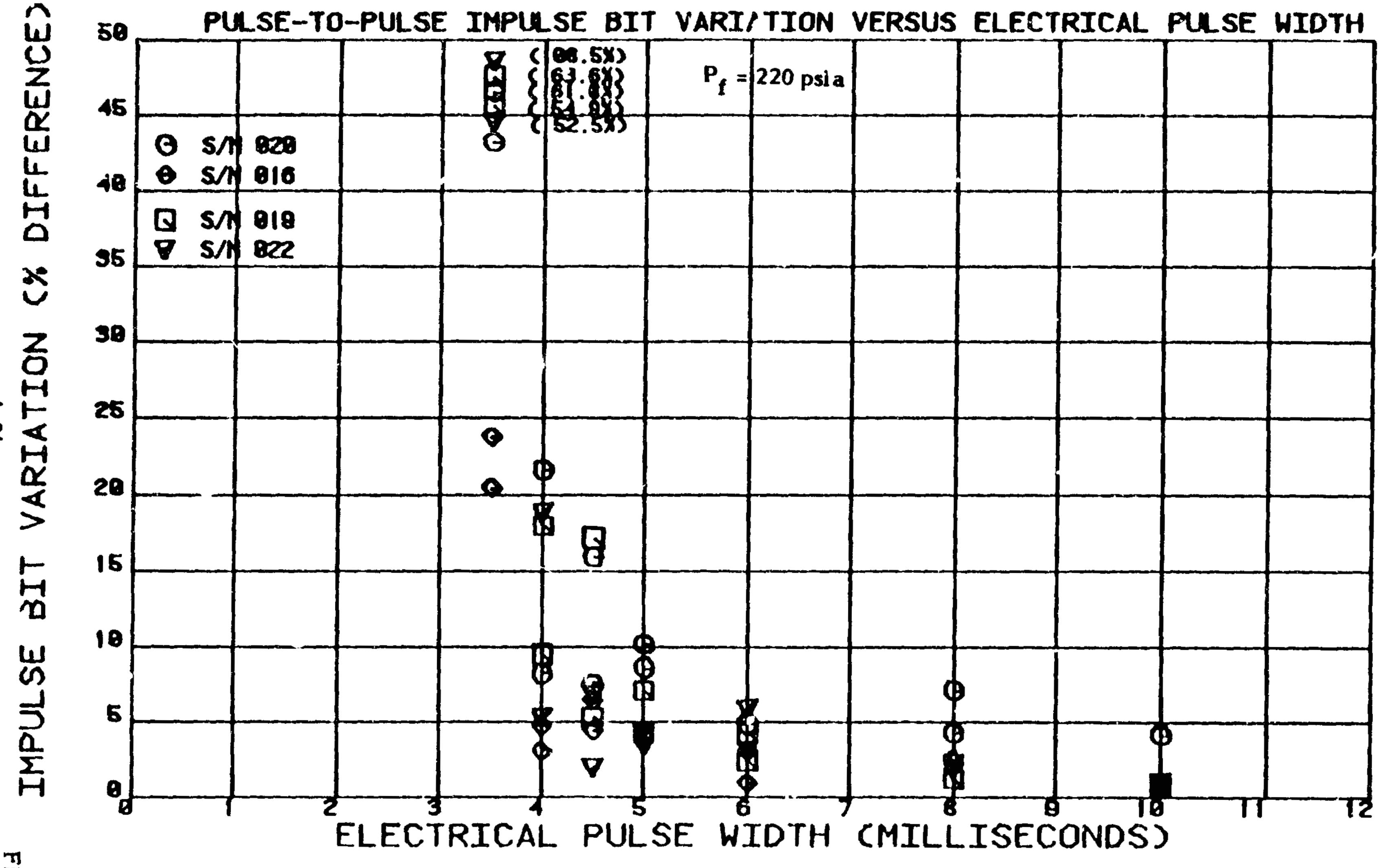


Figure 4-29

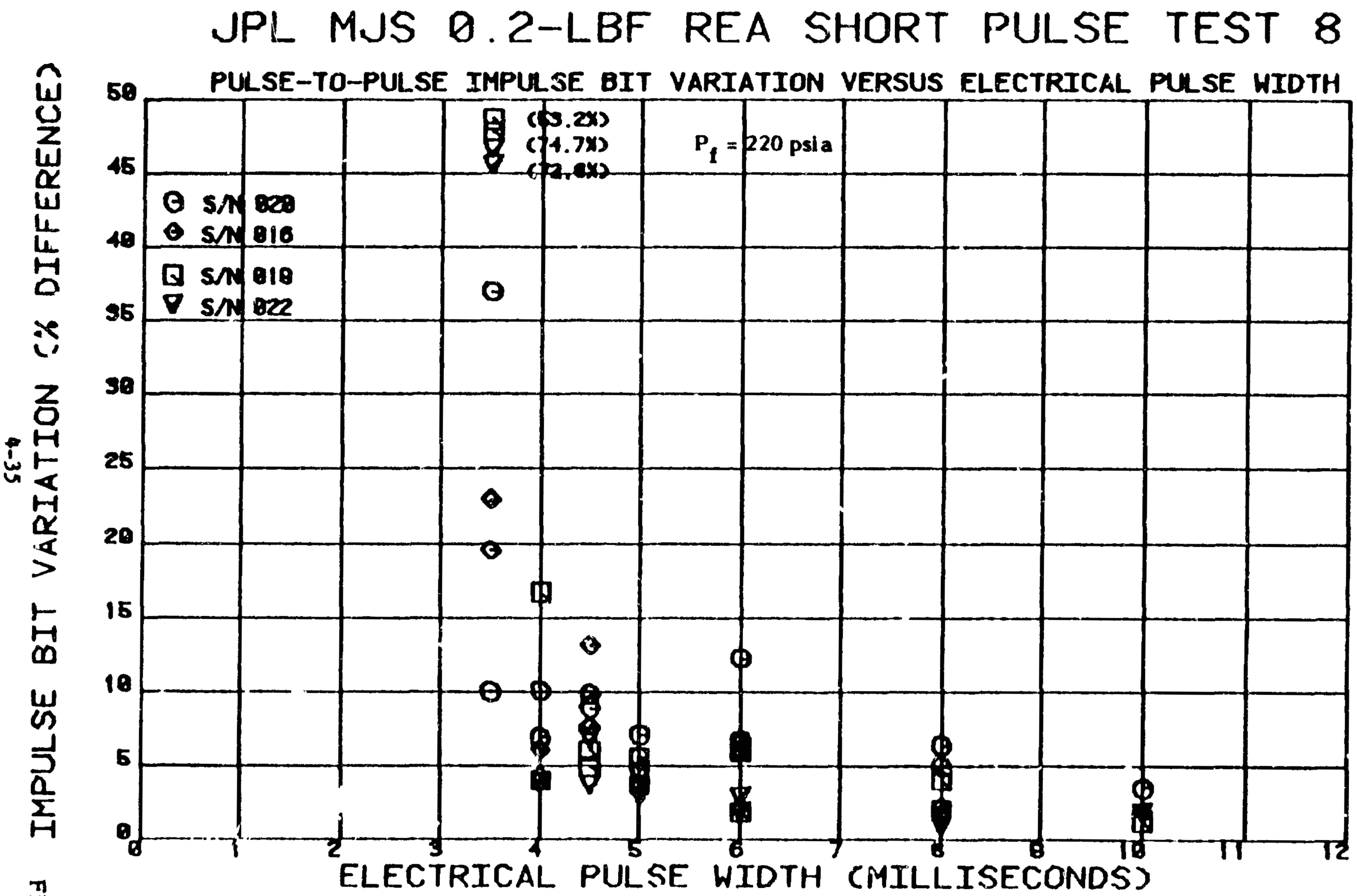
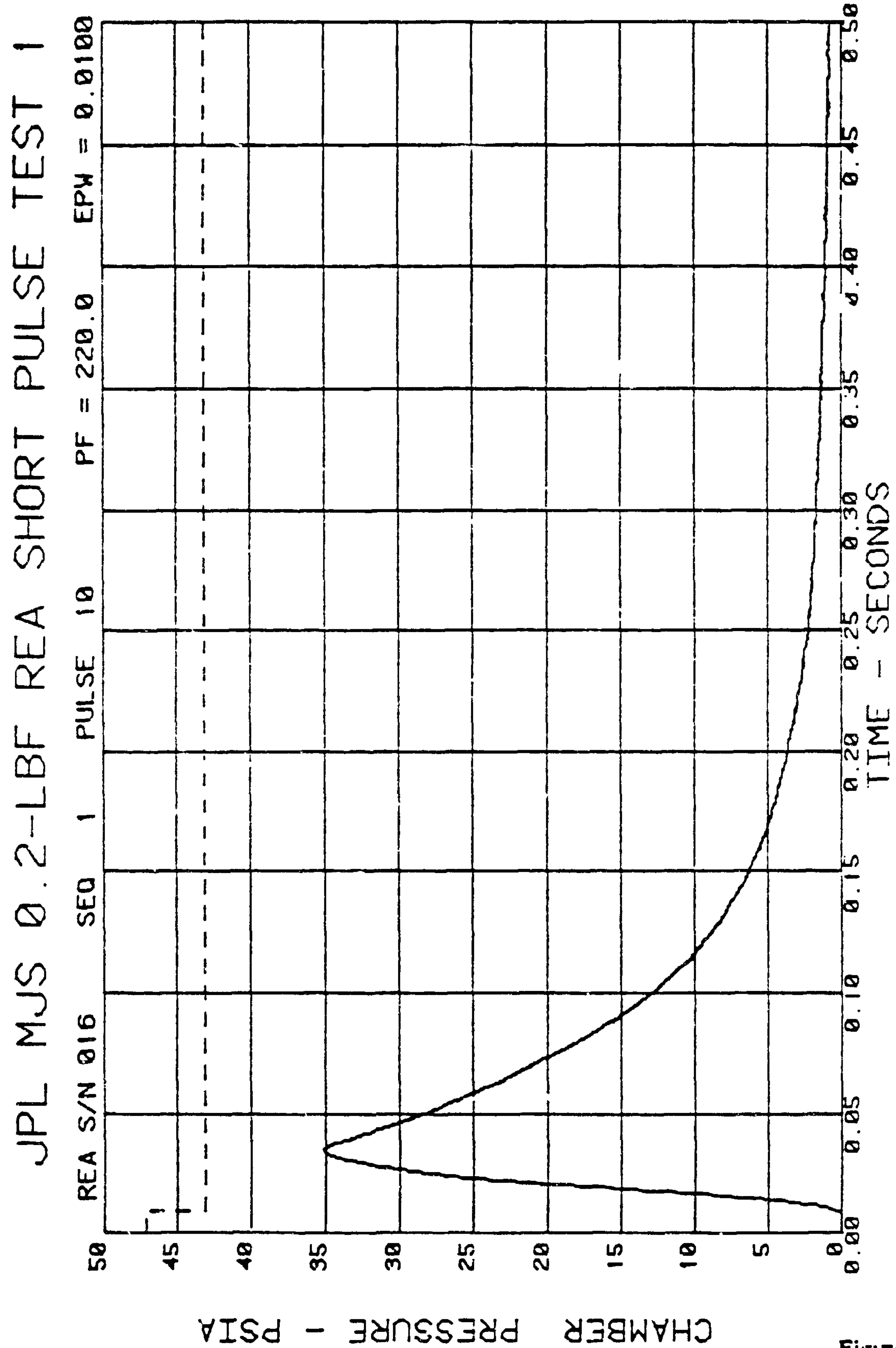

JPL MJS 0.2-LBF REA SHORT PULSE TEST 8
PULSE-TO-PULSE IMPULSE BIT VARIATION VERSUS ELECTRICAL PULSE WIDTH
IMPULSE BIT VARIATION (% DIFFERENCE)
ELECTRICAL PULSE WIDTH (MILLISECONDS)
S/N 820
S/N 816
S/N 818
S/N 822
(53.2%)
(74.7%)
(72.8%)
P_f = 220 psia

Figure 4-30



JPL MJS 0.2-LBF REA SHORT PULSE TEST 1
REA S/N 016 SEQ 1 PULSE 10 PF = 220.0 EPW = 0.0100
CHAMBER PRESSURE - PSIA
TIME - SECONDS
0 5 10 15 20 25 30 35 40 45 50
0.00 0.05 0.10 0.15 0.20 0.25 0.30 0.35 0.40 0.45 0.50

Figure 4-31

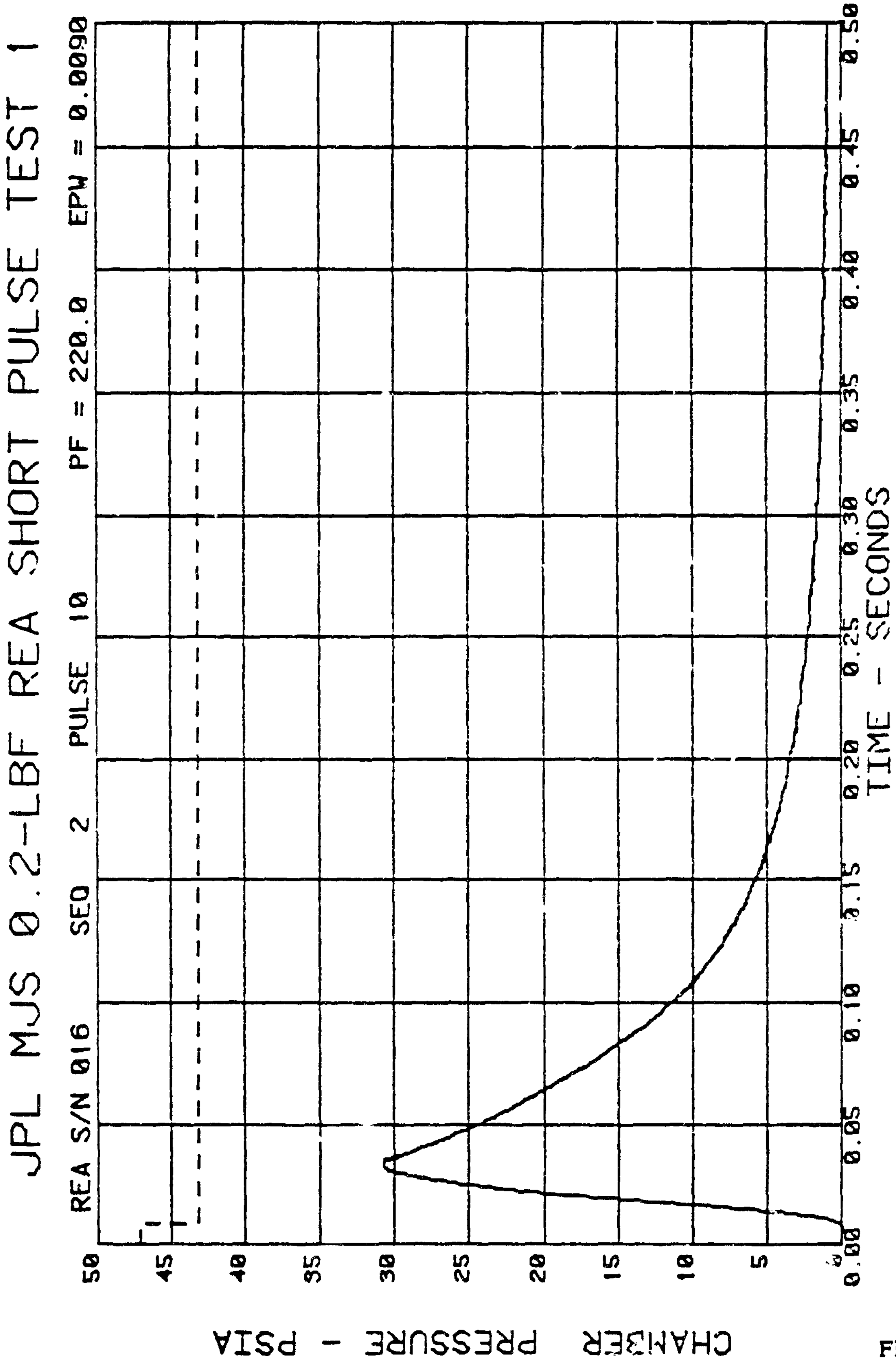

JPL MJS 0.2-LBF REA SHORT PULSE TEST 1
REA S/N 016 SEQ 2 PULSE 10 PF = 220.0 EPW = 0.0090
TIME - SECONDS
CHAMBER PRESSURE - PSIA
0.00 0.05 0.10 0.15 0.20 0.25 0.30 0.35 0.40 0.45 0.50
50 45 40 35 30 25 20 15 10 5 0

Figure 4-32

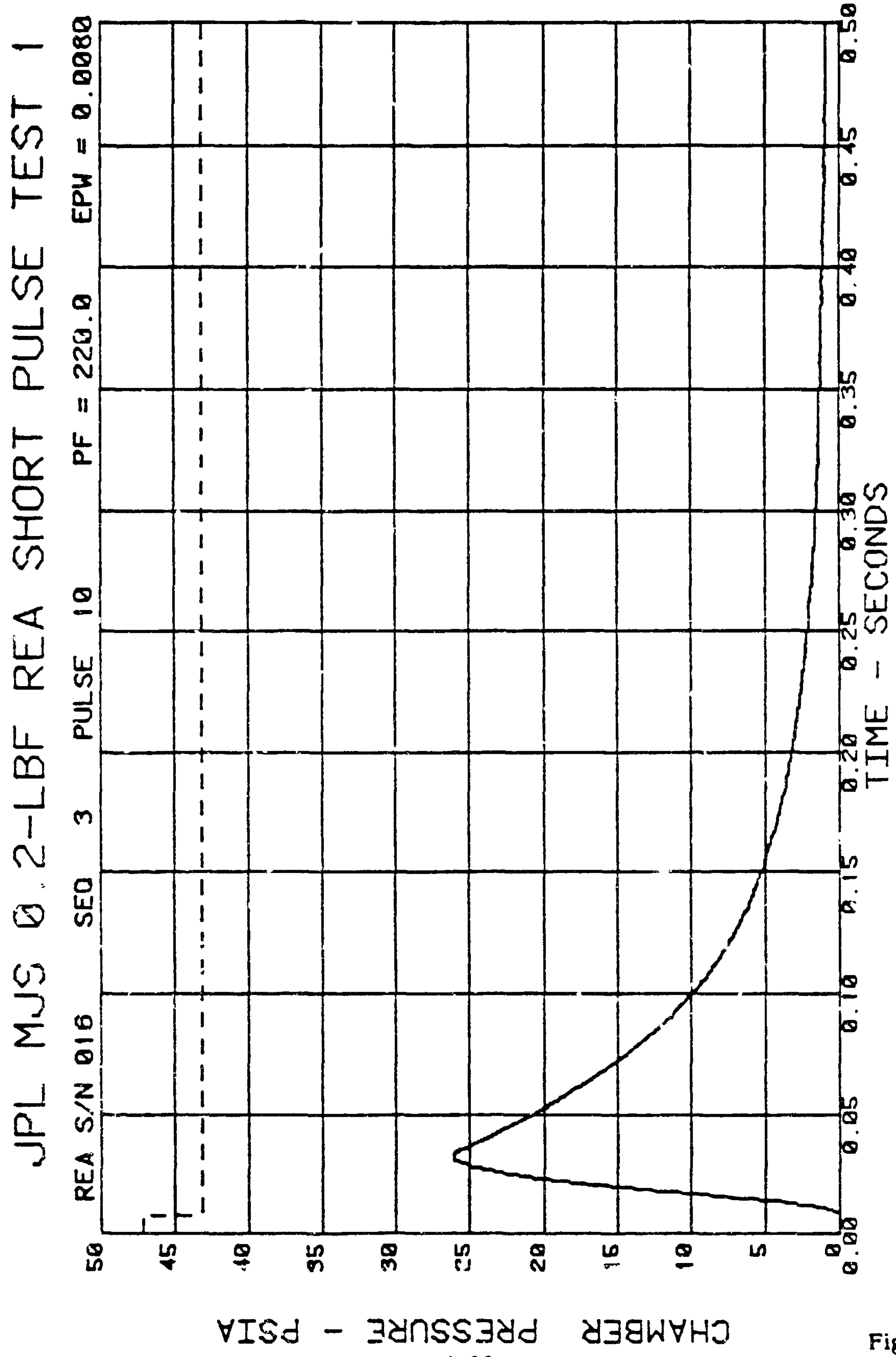

JPL MJS Ø.2-LBF REA SHORT PULSE TEST 1
REA S/N 016 SEQ 3 PULSE 10 PF = 220.0 EPW = 0.0080
TIME - SECONDS
0.00 0.05 0.10 0.15 0.20 0.25 0.30 0.35 0.40 0.45 0.50
CHAMBER PRESSURE - PSIA
0 5 10 15 20 25 30 35 40 45 50

Figure 4-33

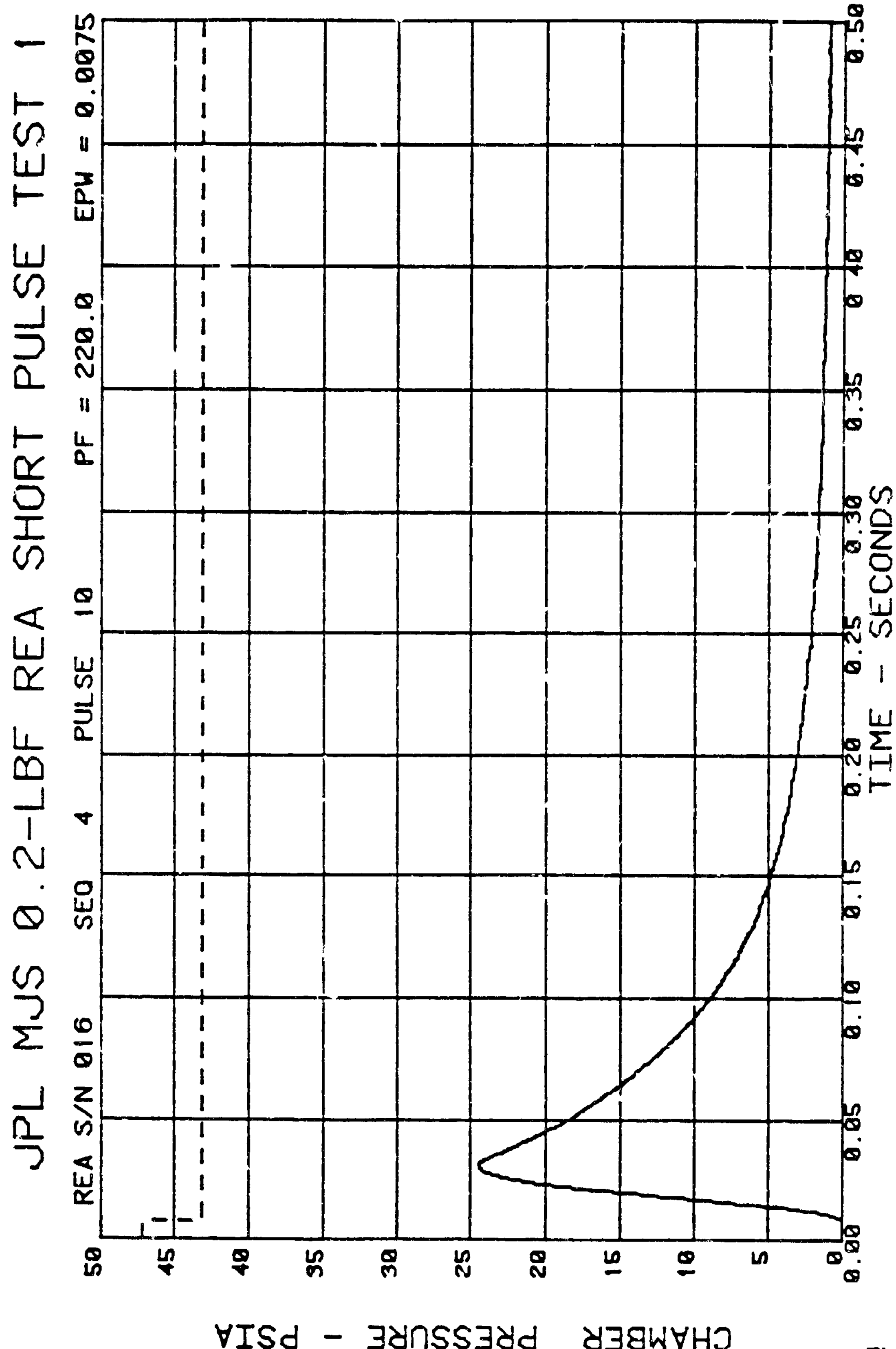

JPL MJS 0.2-LBF REA SHORT PULSE TEST 1
REA S/N 016 SEQ 4 PULSE 10 PF = 220.0 EPW = 0.0075
TIME - SECONDS
0.00 0.05 0.10 0.15 0.20 0.25 0.30 0.35 0.40 0.45 0.50
CHAMBER PRESSURE - PSIA
0 5 10 15 20 25 30 35 40 45 50

Figure 4-34

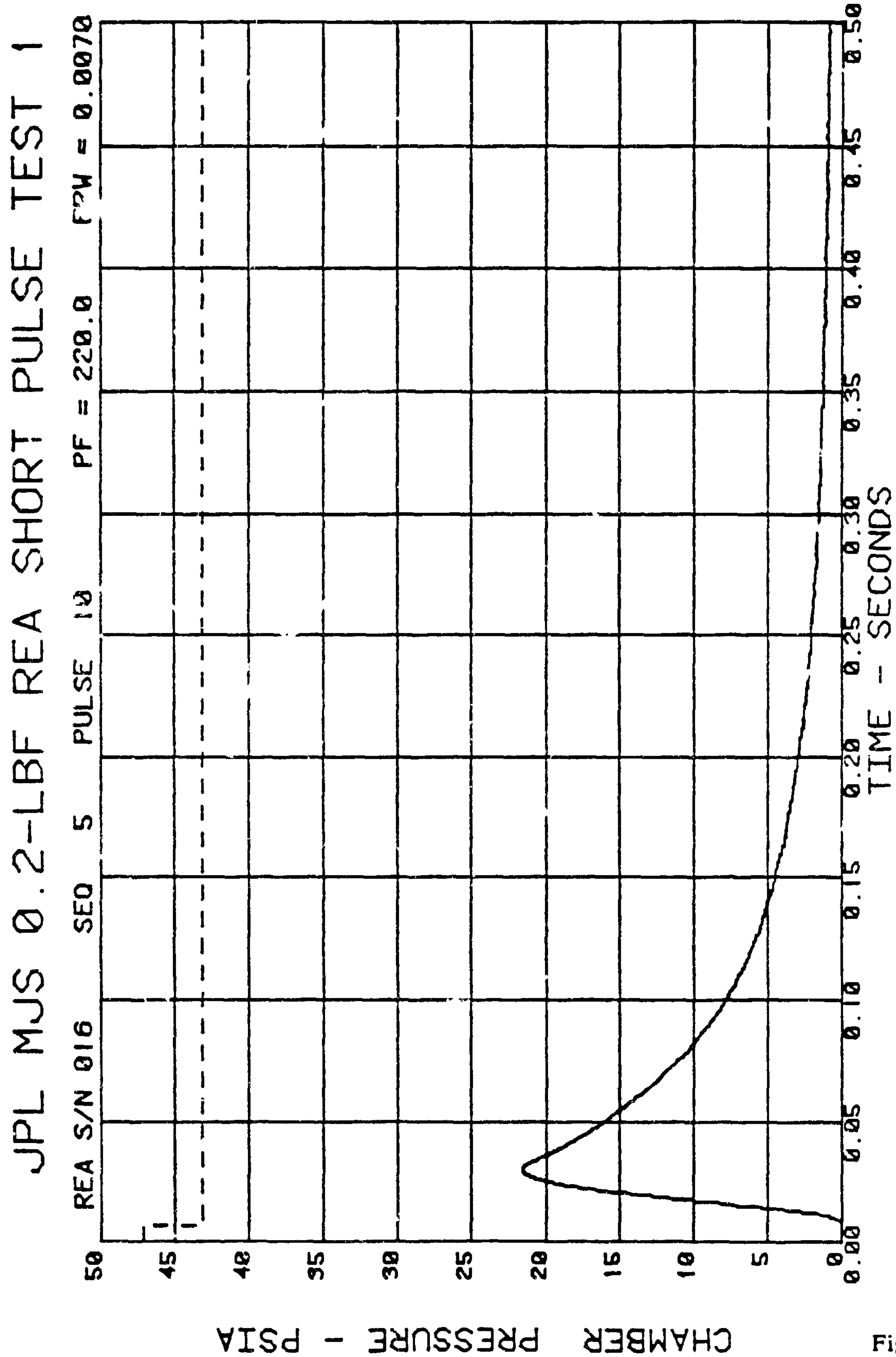

JPL MJS 0.2-LBF REA SHORT PULSE TEST 1
REA S/N 016 SEQ 5 PULSE 10 PF = 220.0 FPW = 0.0070
TIME - SECONDS
0.00 0.05 0.10 0.15 0.20 0.25 0.30 0.35 0.40 0.45 0.50
CHAMBER PRESSURE - PSIA
0 5 10 15 20 25 30 35 40 45 50

Figure 4-35

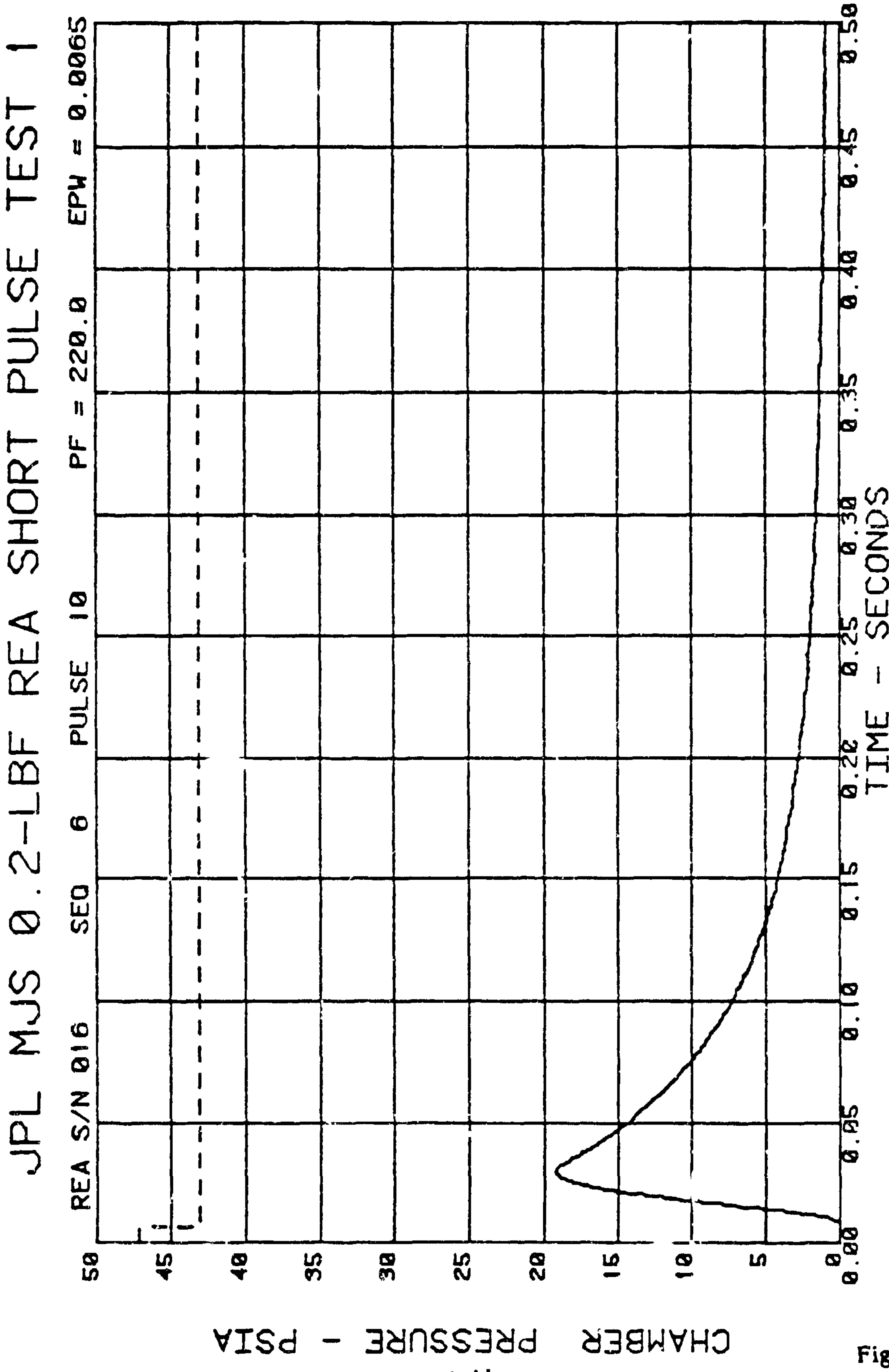

JPL MJS 0.2-LBF REA SHORT PULSE TEST 1
REA S/N 016 SEQ 6 PULSE 10 PF = 220.0 EPW = 0.0065
TIME - SECONDS
CHAMBER PRESSURE - PSIA
0.00 0.05 0.10 0.15 0.20 0.25 0.30 0.35 0.40 0.45 0.50
0 5 10 15 20 25 30 35 40 45 50

Figure 4-36

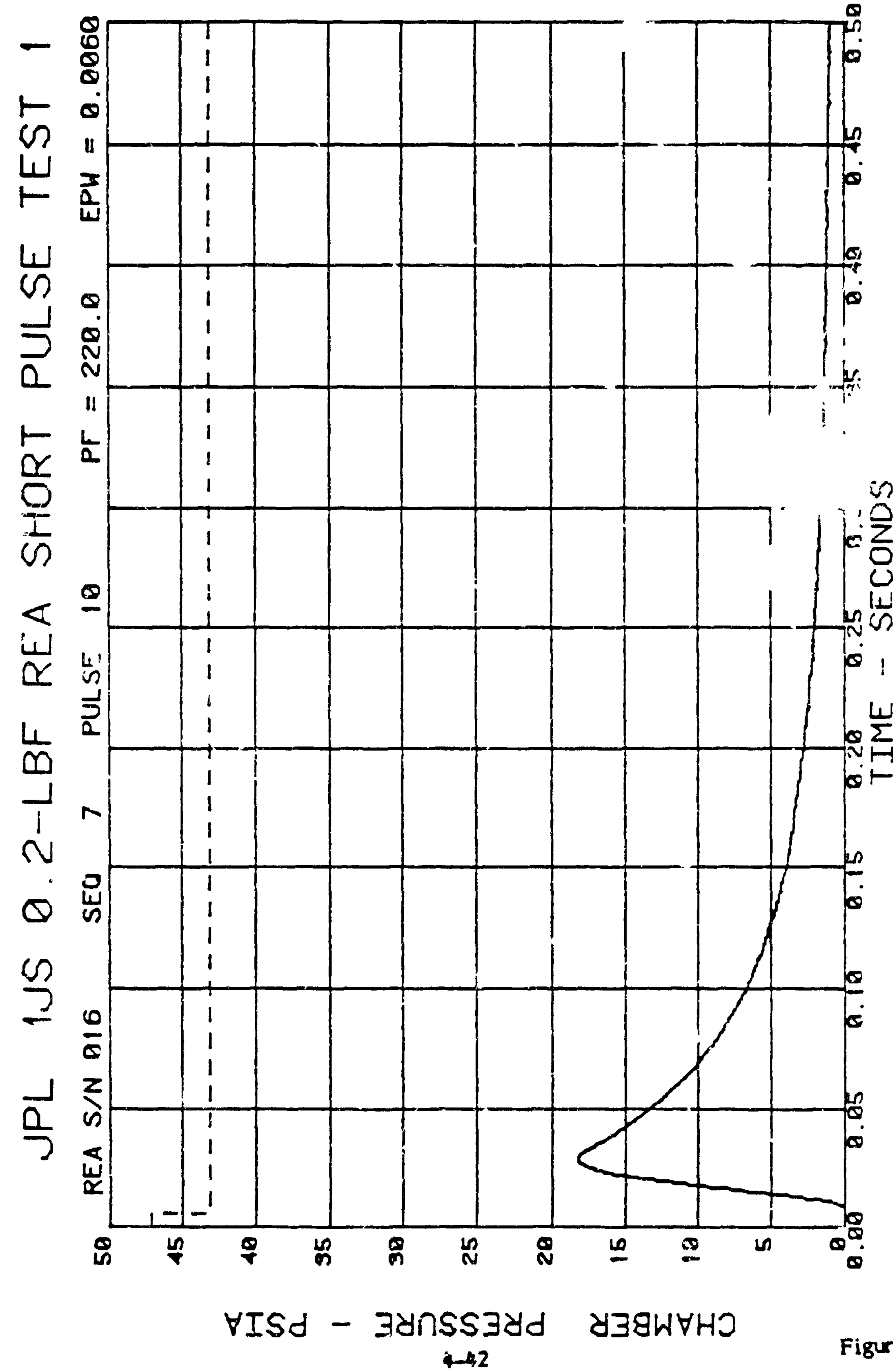

JPL 1JS 0.2-LBF REA SHORT PULSE TEST 1
REA S/N 016
SEQ 7
PULSE 10
PF = 220.0
EPW = 0.0060
CHAMBER PRESSURE - PSIA
TIME - SECONDS
50
45
40
35
30
25
20
15
10
5
0
0.00
0.05
0.10
0.15
0.20
0.25
0.40
0.45
0.50

Figure 4-37

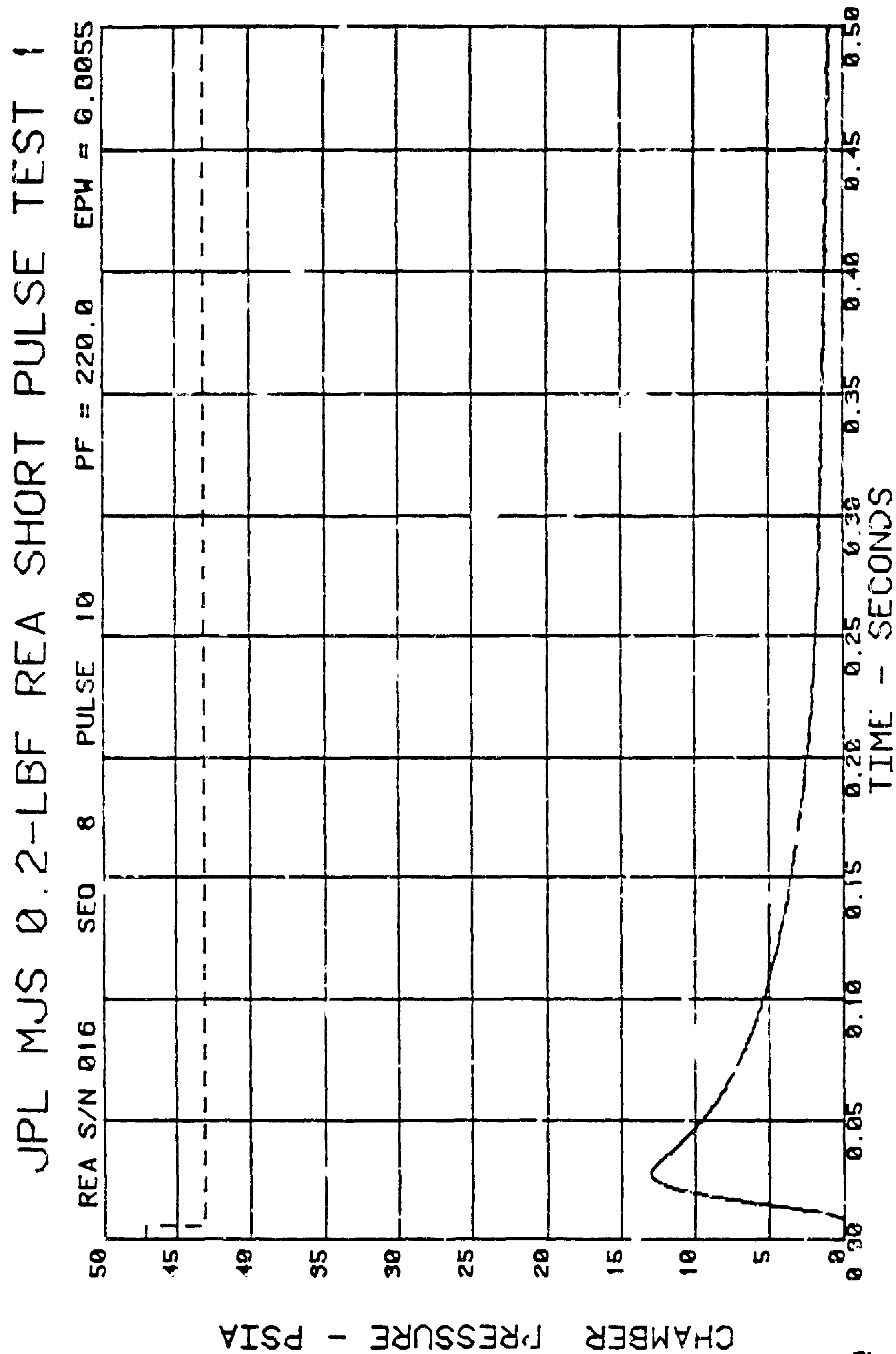

JPL MJS 0.2-LBF REA SHORT PULSE TEST 1
REA S/N 016 SEQ 8 PULSE 10 PF = 220.0 EPW = 0.0055
TIME - SECONDS
CHAMBER PRESSURE - PSIA

Figure 4-38

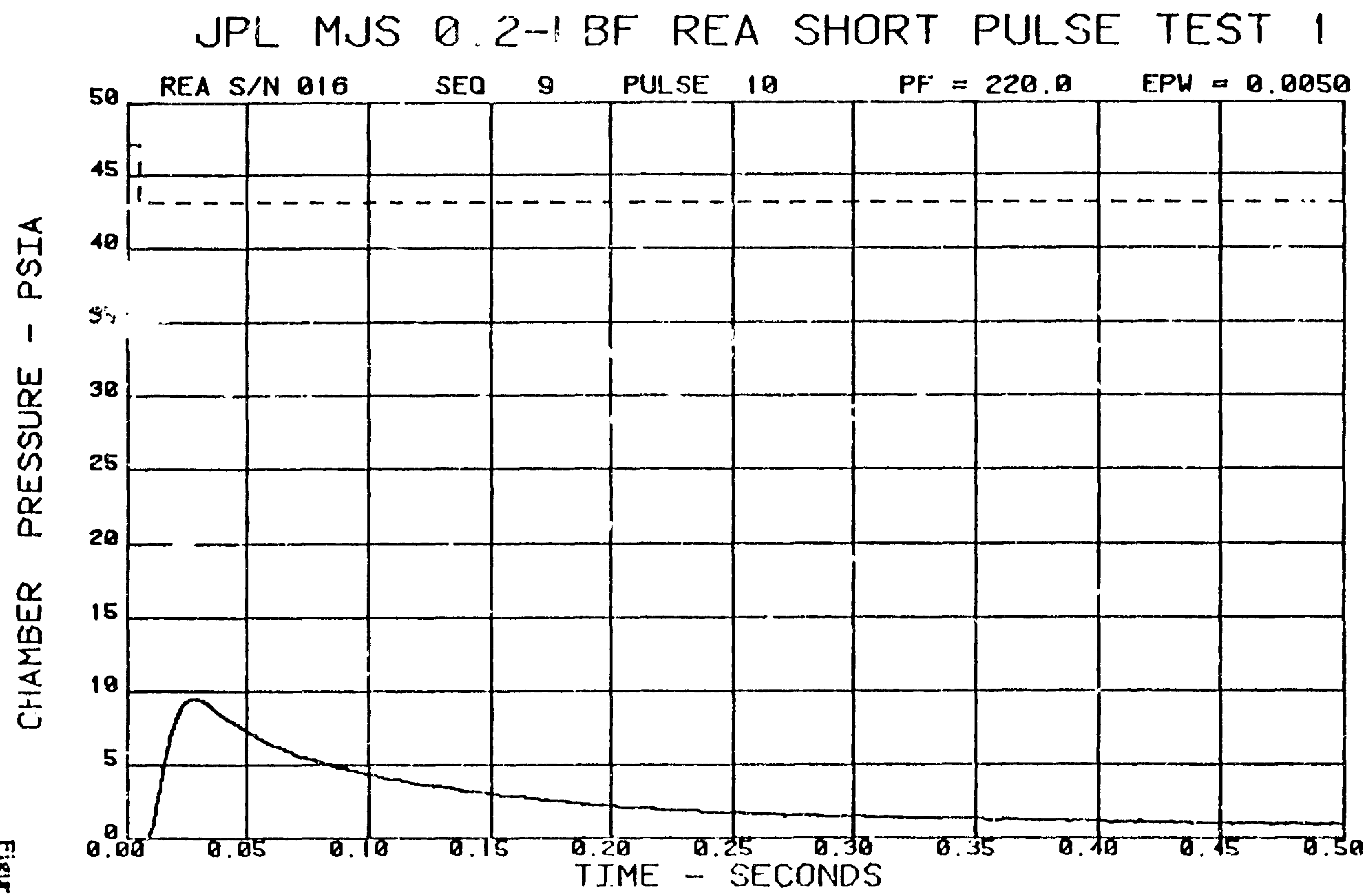

JPL MJS 0.2-l BF REA SHORT PULSE TEST 1
REA S/N 016
SEQ 9
PULSE 10
PF = 220.0
EPW = 0.0050
CHAMBER PRESSURE - PSIA
TIME - SECONDS
0
5
10
15
20
25
30
40
45
50
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
0.45
0.50

Figure 4-39

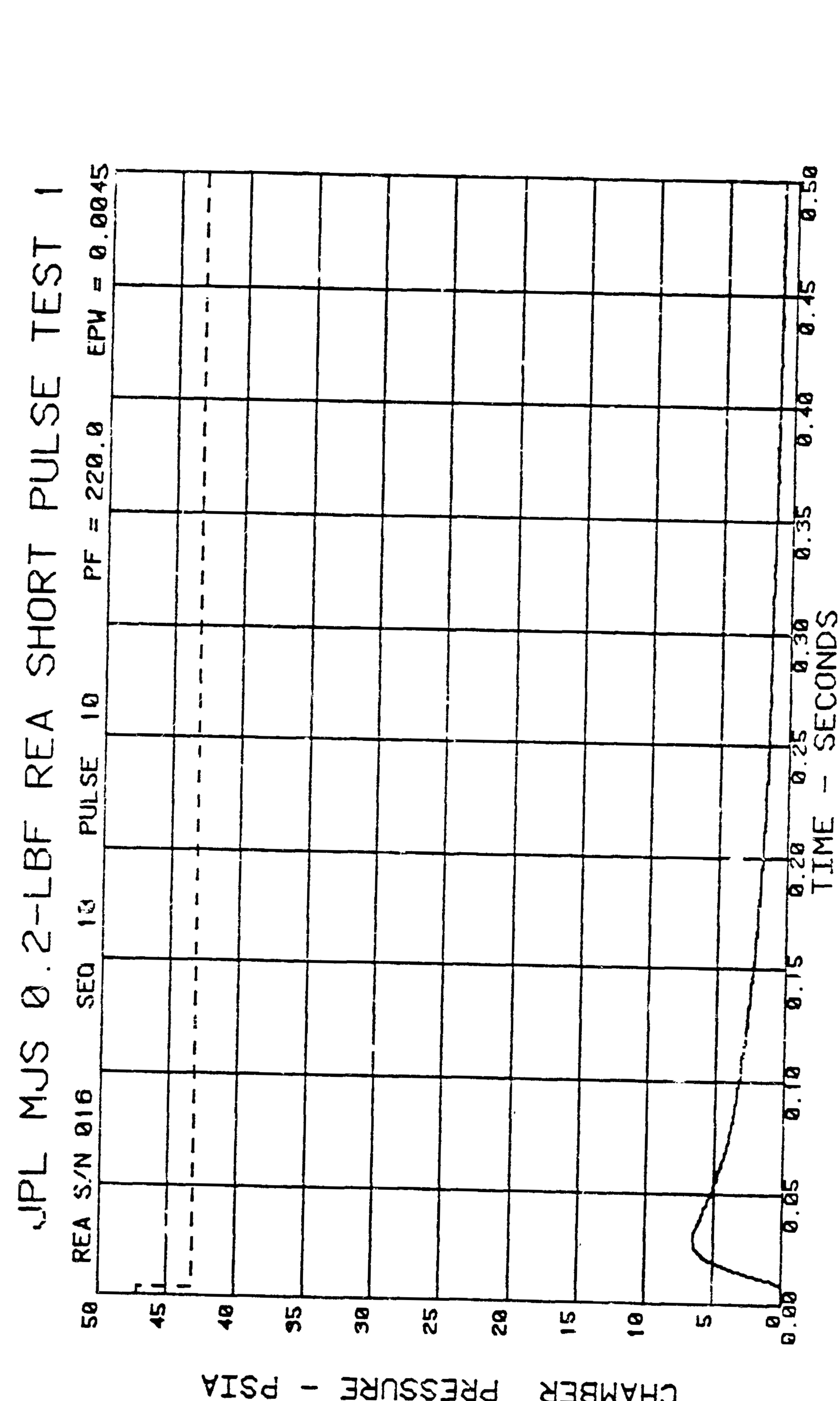
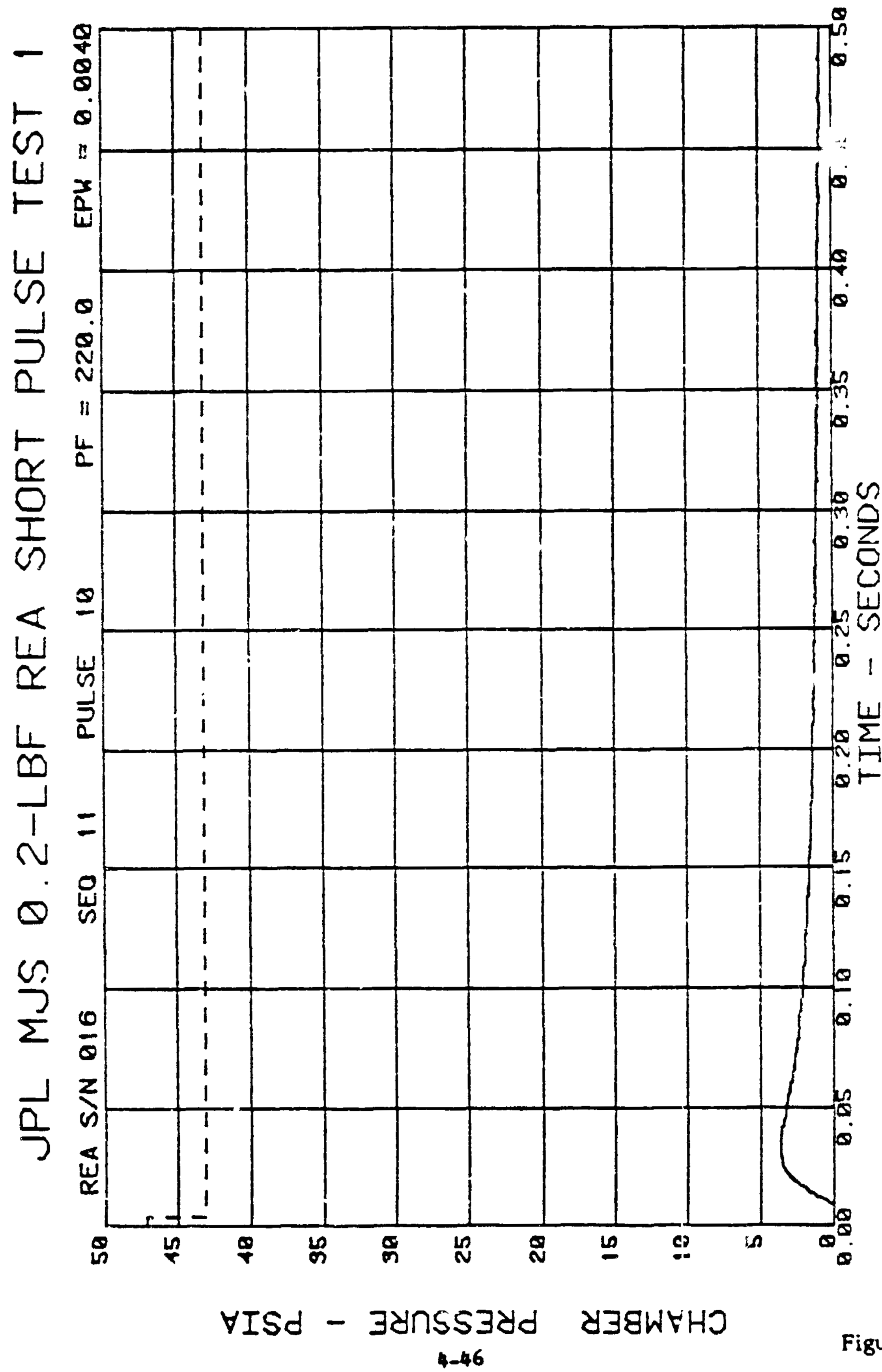

JPL MJS Ø.2-LBF REA SHORT PULSE TEST 1
REA S/N Ø16 SEQ 10 PULSE 10 PF = 220.0 EPW = 0.0045
CHAMBER PRESSURE - PSIA
TIME - SECONDS
0 5 10 15 20 25 30 35 40 45 50
0.00 0.05 0.10 0.15 0.20 0.25 0.30 0.35 0.40 0.45 0.50

Figure 4-40



JPL MJS 0.2-LBF REA SHORT PULSE TEST 1
REA S/N 016
SEQ 11
PULSE 10
PF = 220.0
EPW = 0.0040
TIME - SECONDS
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
0.50
CHAMBER PRESSURE - PSIA
0
5
10
15
20
25
30
35
40
45
50

Figure 4-4i

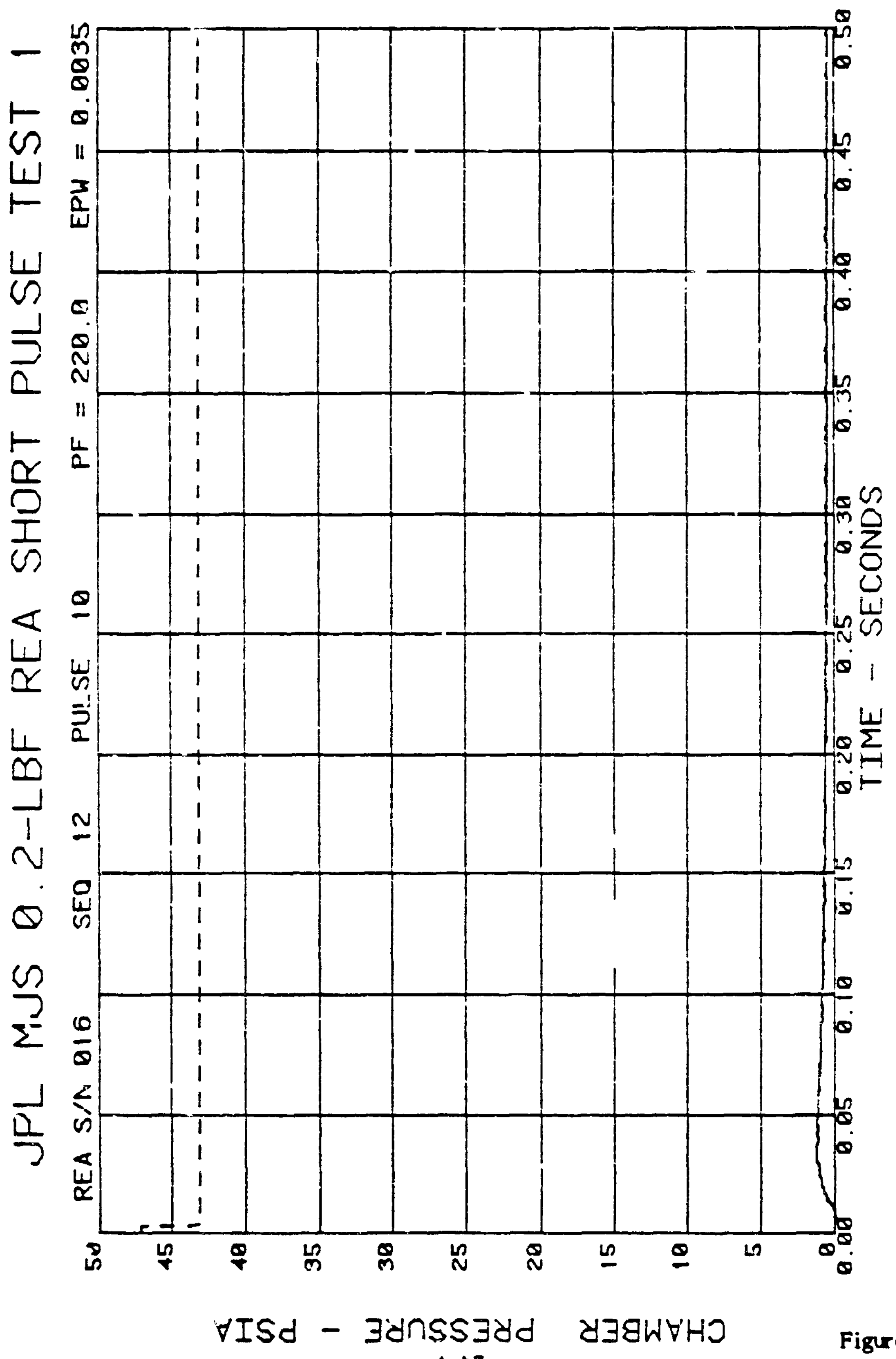

JPL MJS 0.2-LBF REA SHORT PULSE TEST 1
REA S/N 016 SEQ 12 PULSE 10 PF = 220.0 EPW = 0.0035
TIME - SECONDS
0.00 0.05 0.10 0.15 0.20 0.25 0.30 0.35 0.40 0.45 0.50
CHAMBER PRESSURE - PSIA
0 5 10 15 20 25 30 35 40 45 50

Figure 4-42

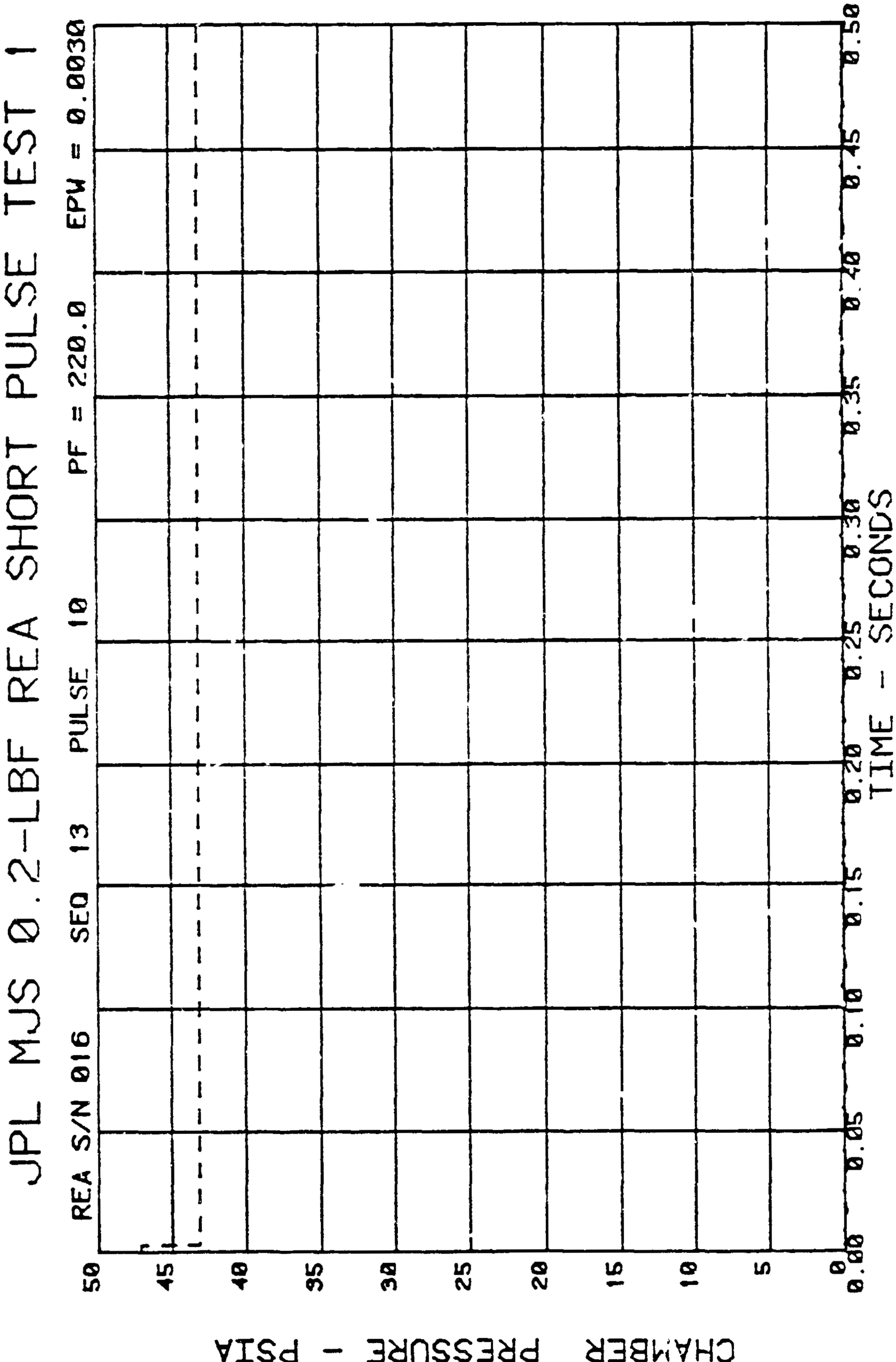

JPL MJS Ø.2-LBF REA SHORT PULSE TEST 1
REA S/N Ø16
SEQ 13
PULSE 1Ø
PF = 22Ø.Ø
EPW = Ø.ØØ3Ø
CHAMBER PRESSURE - PSIA
TIME - SECONDS
50
45
40
35
30
25
20
15
10
5
0
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
0.45
0.50

Figure 4-43

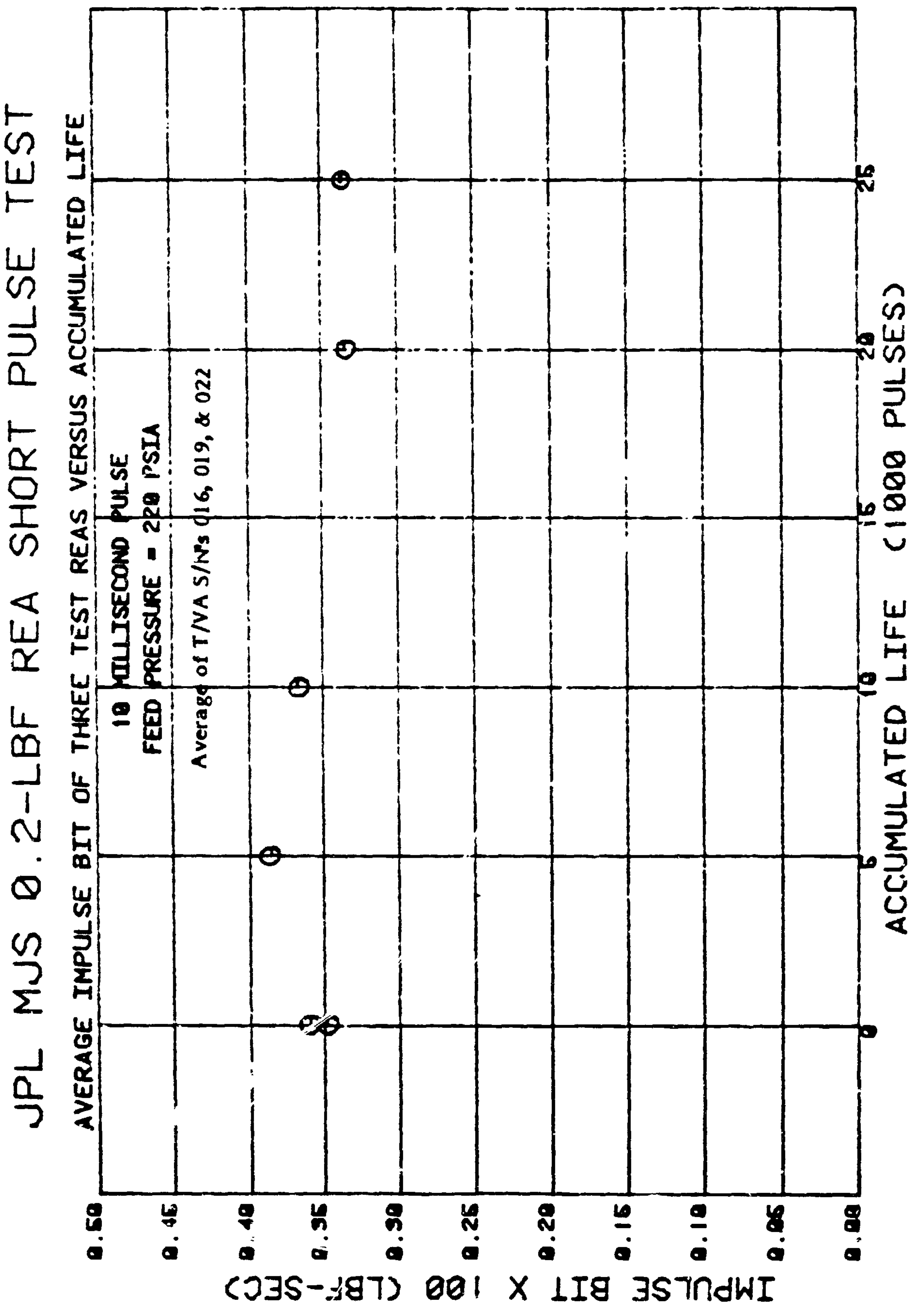

JPL MJS 0.2-LBF REA SHORT PULSE TEST
AVERAGE IMPULSE BIT OF THREE TEST REAS VERSUS ACCUMULATED LIFE
10 MILLISECOND PULSE
FEED PRESSURE = 220 PSIA
Average of T/VA S/Ns 016, 019, & 022
0
5
10
15
20
25
ACCUMULATED LIFE (1000 PULSES)
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
IMPULSE BIT X 100 (LBF-SEC)

Figure 4-44

JPL MJS 0.2-LBF REA SHORT PULSE TEST

AVERAGE IMPULSE BIT OF FOUR TEST REAS VERSUS ACCUMULATED LIFE

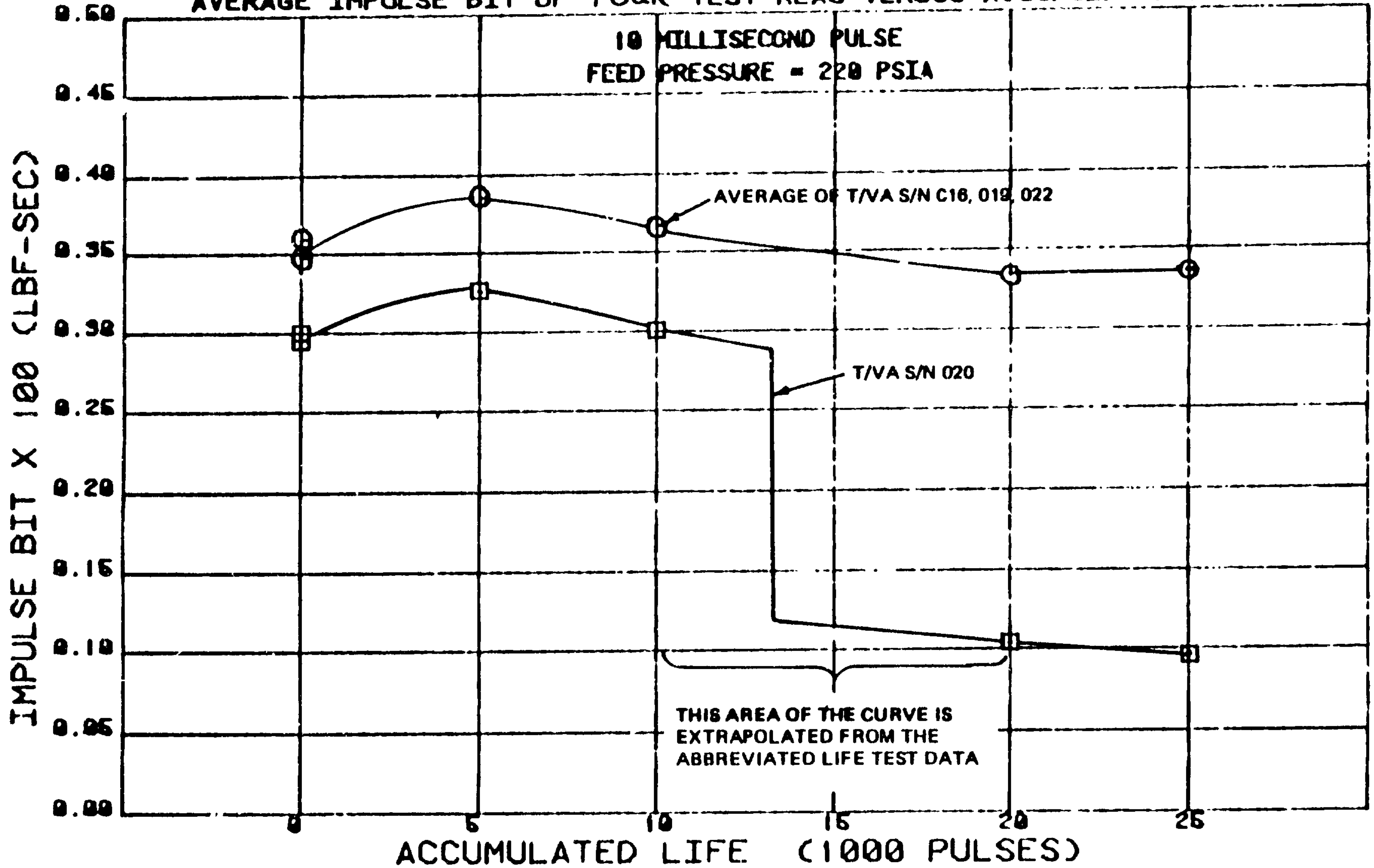


Figure 4-45

5.0 DISASSEMBLY AND INSPECTION OF T/VA S/N 020

In order to determine the cause of the partial flow blockage of thruster valve assembly (T/VA) S/N 020, the following operations were performed:

- The thruster nozzle was inspected and found to be clean and unobstructed.

- The valve was removed from the thruster and the valve outlet was inspected. No contaminants were found.

- The thruster upstream screen was inspected. No evidence of contamination was found.

- A GN_2 flow test was performed on the valve and the flow was normal.

- A GN_2 flow test was performed on the thruster and the flow was found to be the same as the flow recorded during the postfire flow test; i.e., 28 ml/min. at 5 psig and 36 ml/min. at 10 psig. This is an 85% flow reduction from the prefire flow test.

- The thrust chamber body was separated and the catalyst granules were separate and appeared normal except for slight caking of catalyst in the portion of the catalyst bed closest to the capillary tube outlet. The cake was loose and easily disintegrated. Hydrogen chemisorption tests were performed on the catalyst removed from the upstream end of the bed and the middle of the bed. The results were 103 and 121 μ moles/g, respectively. The hydrogen chemisorption test gives an indication of the active catalyst surface area. A hydrogen chemisorption of 120 is considered acceptable for new catalyst.

- The bedplate was observed to be clean and free from contamination.

- The upstream injector screen was clean and free from contamination. The screen was removed and the capillary tube inlet was observed to be clean and free from contamination.

- The downstream injector screens were removed and were observed to have catalyst fines coating the outer edges but the screens were not obstructed. The area in the middle of the screens was very clean.

- The downstream end of the injector was inspected and cause of the partial flow blockage was observed. There was material buildup in the area of the capillary tube. The photograph on Figure 5-1 shows the material buildup causing partial blockage of the capillary tube. Figure 5-2 is a photograph of a section through the downstream end of the injector showing the material buildup in the capillary tube.

ORIGINAL PAGE IS
OF POOR QUALITY

25X

0.2 lbf T/VA S/N 020 – VIEW OF DOWNSTREAM END OF INJECTOR SHOWING PARTIAL FLOW BLOCKAGE OF THE CAPILLARY TUBE

100X

0.2 lbf T/VA S/N 020 — SECTION THROUGH DOWNSTREAM END OF INJECTOR SHOWING PARTIAL FLOW BLOCKAGE OF THE CAPILLARY TUBE

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 CONCLUSIONS

After a thorough review and consideration of the information contained in this report, the conclusions are as follows:

- The limiting electrical pulse width is 3.0 milliseconds. The valve will not unseat on most T/VA's and therefore no impulse will be obtained.

- A 3.5-millisecond electrical pulse would yield an impulse bit of approximately 20% of a 10-millisecond pulse impulse bit, but there would be a wide variation in pulse-to-pulse and thruster-to-thruster repeatability.

- A 4.0-millisecond electrical pulse would yield an impulse bit of approximately 45% of a 10-millisecond pulse impulse bit and there would be reasonable pulse-to-pulse and thruster-to-thruster repeatability.

- The performance information on T/VA's S/N's 016, 019 and 022 would suggest that none or only minor degradation in thruster life is due to the 25,000 short pulses. The partial flow blockage associated with T/VA S/N 020 suggests that short pulses could seriously reduce thruster life, however, this thruster may have had a substantial buildup of material in the thruster injector capillary tube prior to this short pulse testing. A definite conclusion on the effect of short pulse on thruster life cannot be formulated from the information resulting from this test program.

6.2 RECOMMENDATIONS

Based on the information contained in this report, the following actions are recommended:

- Use an electrical pulse width of 3.7 milliseconds, as it appears to be the best compromise between a small impulse bit and pulse-to-pulse and thruster-to-thruster impulse bit repeatability. A 3.7-millisecond electrical pulse would yield an impulse bit of approximately 30% of a 10-millisecond pulse impulse bit.

- Continue life testing in order to better define thruster life.

- Section additional thruster injector capillary tubes at the completion of life testing.